SPECS

Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Forecasting the climate response to volcanoes

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SPECS Meeting, Sweden, Norrköping, September 2015

SEVENTH FRAMEWORK PROGRAMME

Introduction

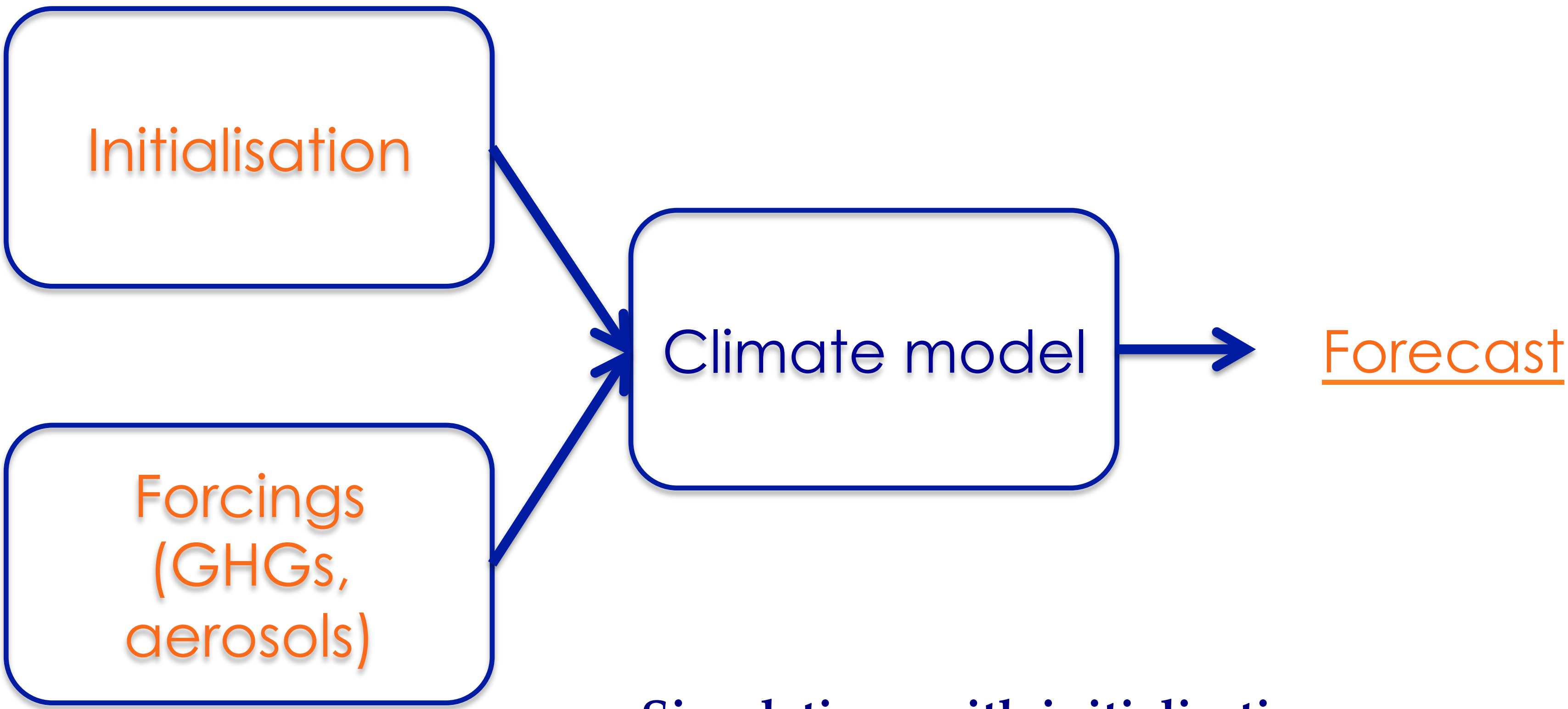
→ **Major eruptions bring large amounts (Tg) of particles in the stratosphere.**

→ **Recent eruptions: Agung (1963), El Chichon (1982) and Pinatubo (1991).**

→ **Global temperature decrease by 0.1-0.5°C, atmospheric impacts noticeable during 5 years, and potential effects on ocean circulation during 10-20 years.**

Sarychev volcano, 2009, NASA

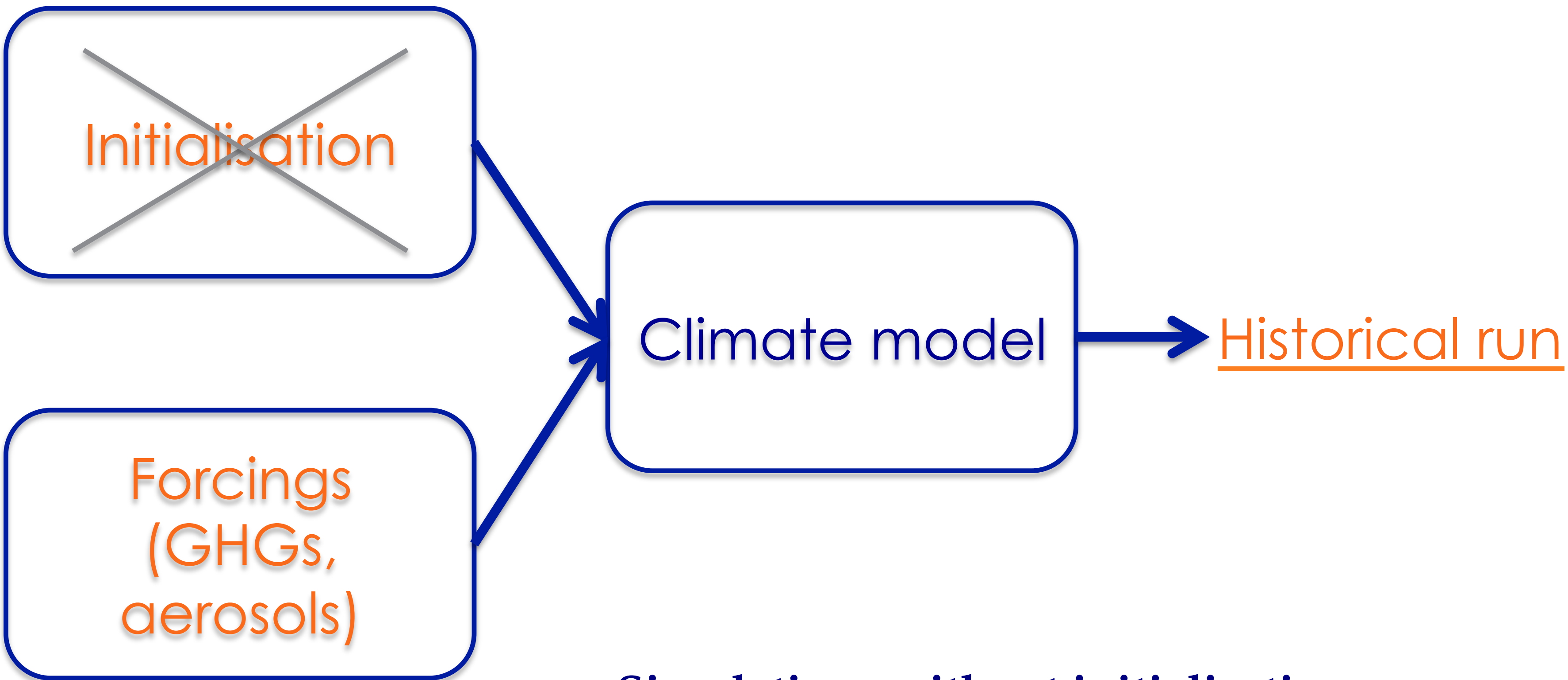
Introduction



→ **Simulations with initialisation**

→ **Simulations with estimation of future forcing**

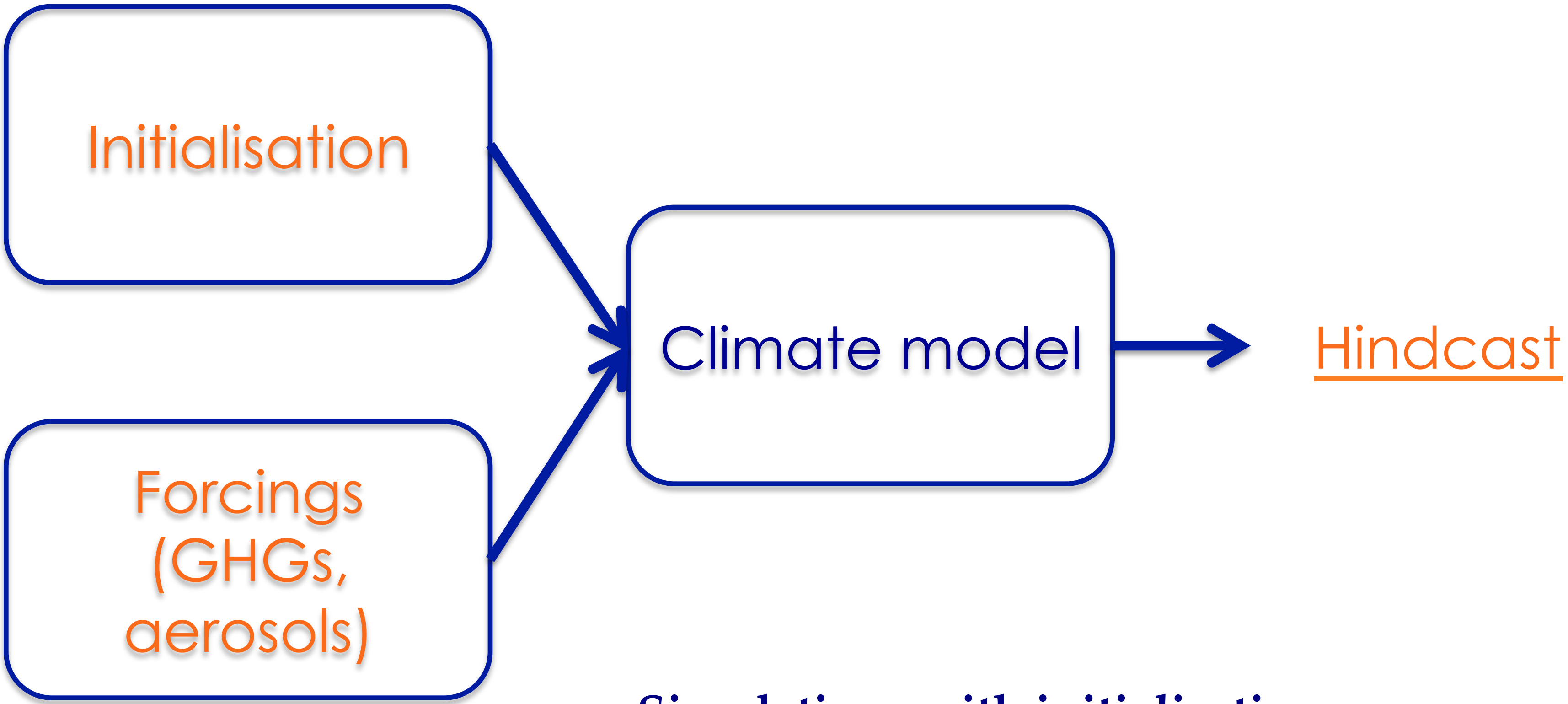
Introduction



→ **Simulations without initialisation**

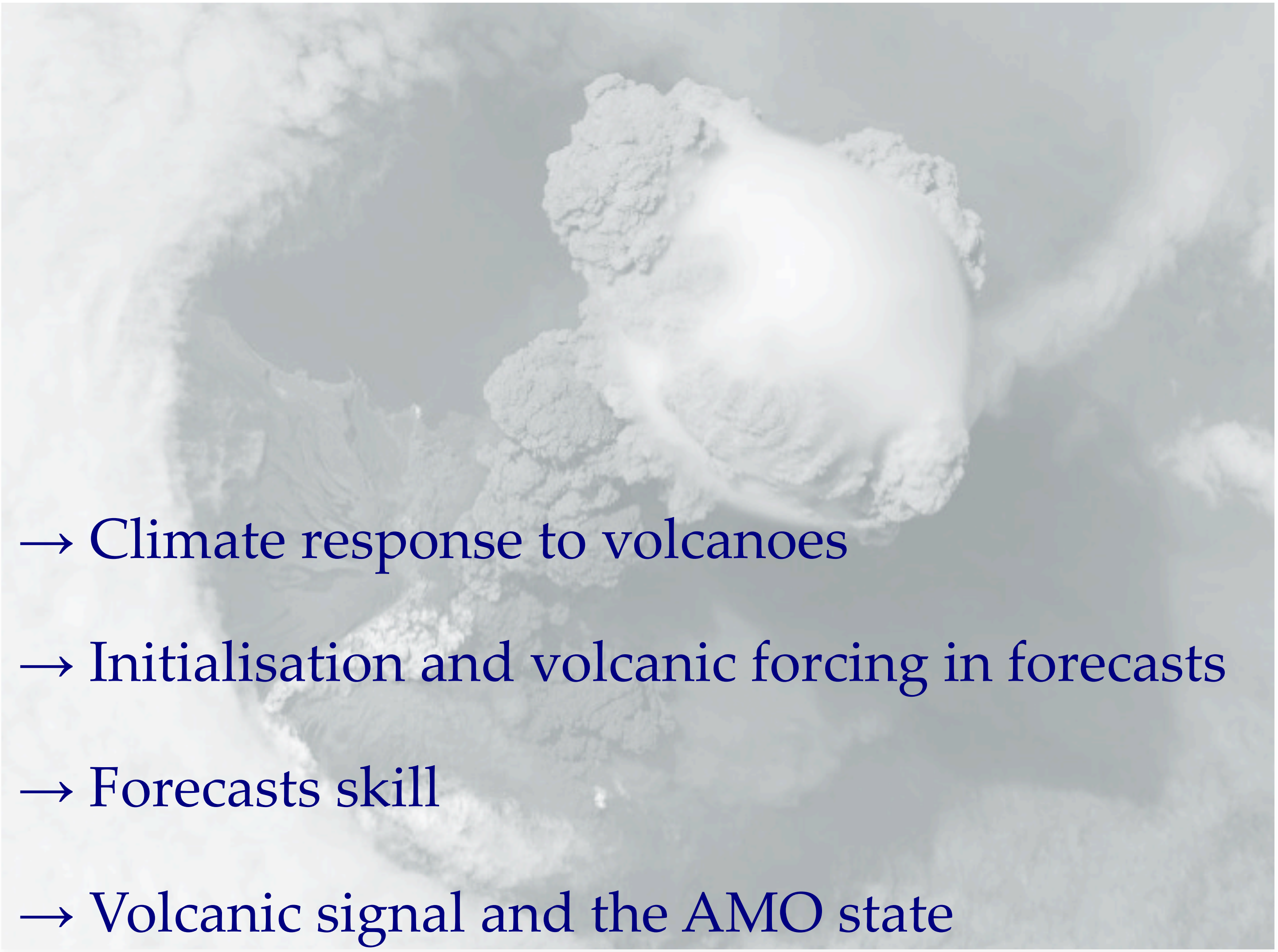
→ **Simulations with observed forcing**

Introduction



→ **Simulations with initialisation**

→ **Simulations with observed forcing**



→ Climate response to volcanoes

→ Initialisation and volcanic forcing in forecasts

→ Forecasts skill

→ Volcanic signal and the AMO state

→ **Climate response to volcanoes**

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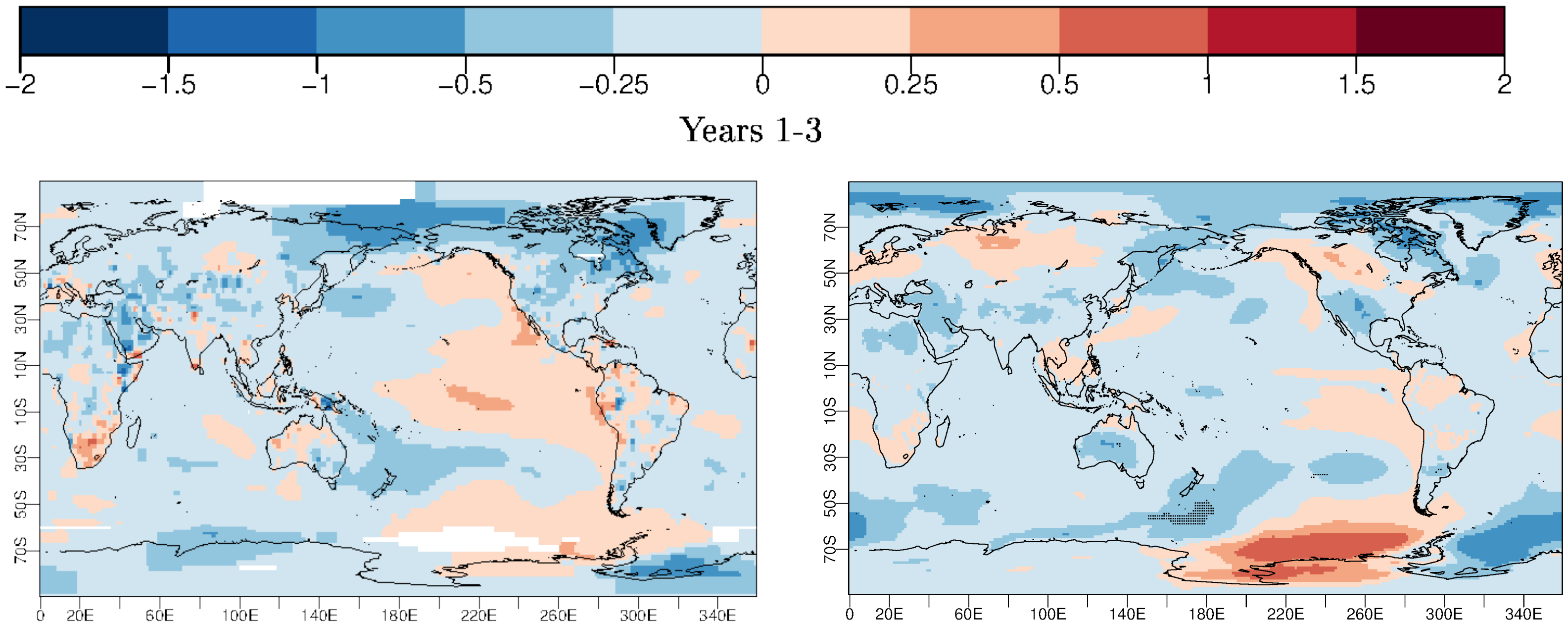
Climate response to volcanoes

→ Large inter-annual variability partly overwhelms the volcanic signal

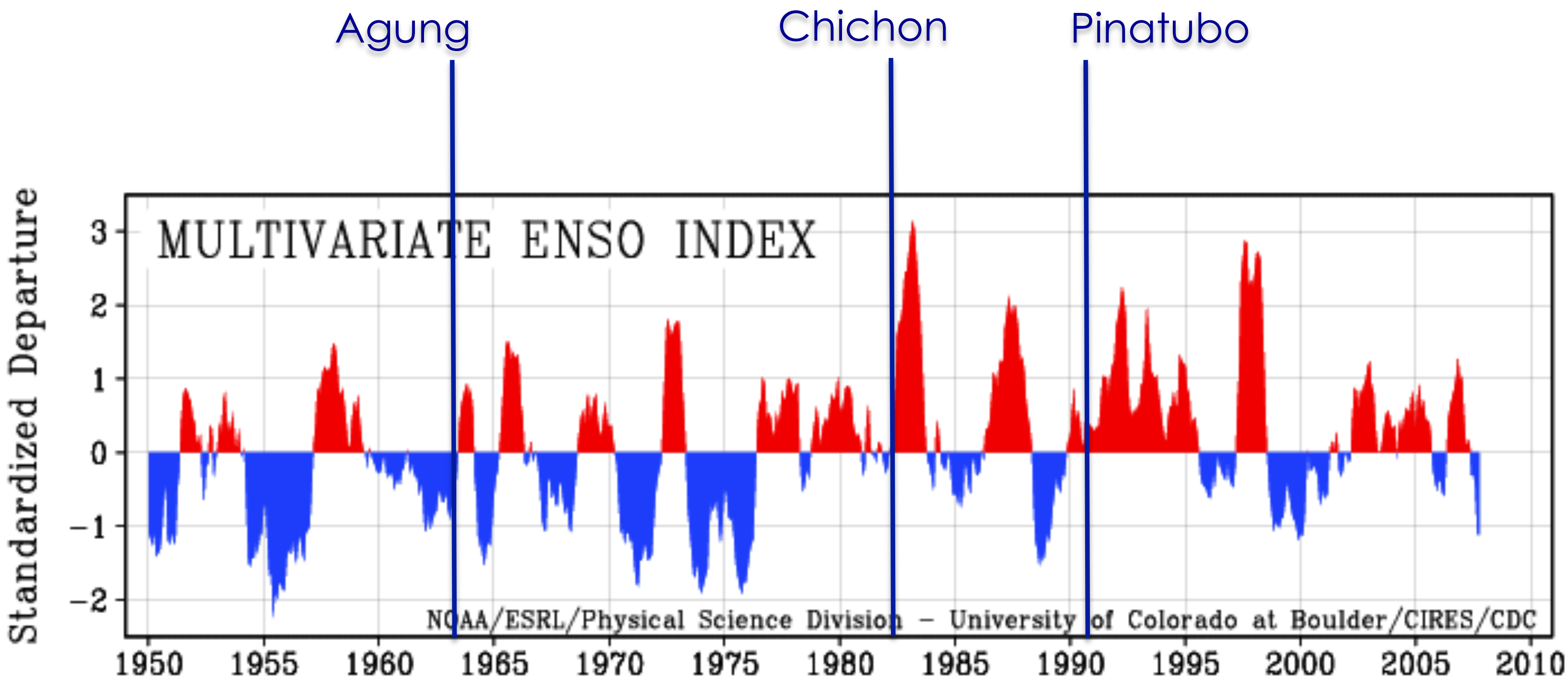


(a) Observation *(b) Model*

Surface temperature anomalies over forecast years 1-3 after the last 3 major eruptions: (a) Observation; (b) EC-Earth hindcasts. Anomalies are averaged over 3 start dates (and 5 members for the simulations). Shaded areas show regions with significant differences with a 5% level, areas without observations appear in white.

Climate response to volcanoes

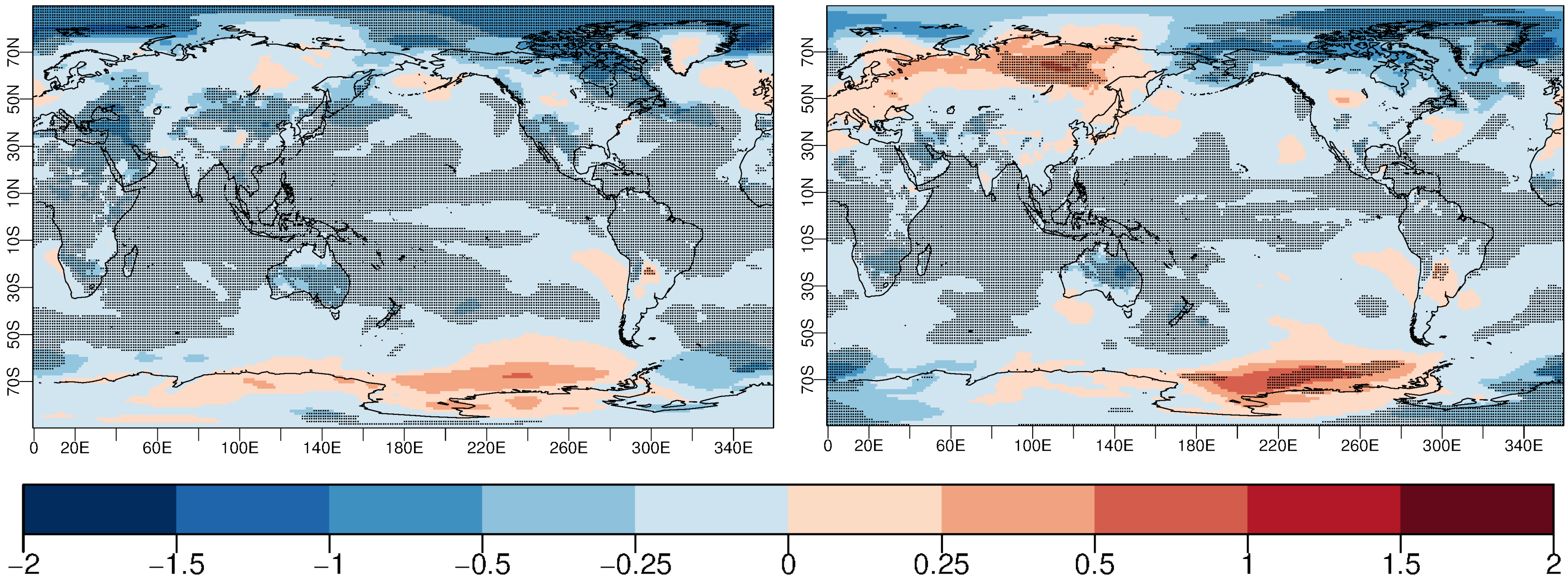
→ **Mixing between ENSO and volcanoes signals !**



Climate response to volcanoes

Sensitivity experiment with - without volcanoes

Years 1-3 **Years 3-5**



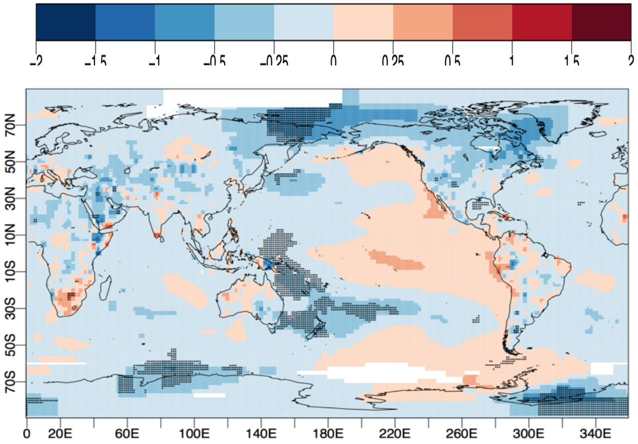
Surface temperature difference (°C). 3-year average after the 3 last major eruptions (Agung, 1963, Chichon, 1982 and Pinatubo, 1991). Difference has been computed between two 5-members hindcasts, one including and another excluding volcanic forcing of large eruptions, and appears shaded when significant with a 5% level.

→ Climate response to volcanoes

→ **Initialisation and volcanic forcing in forecasts**

→ Forecasts skill

Initialisation and volcanoes

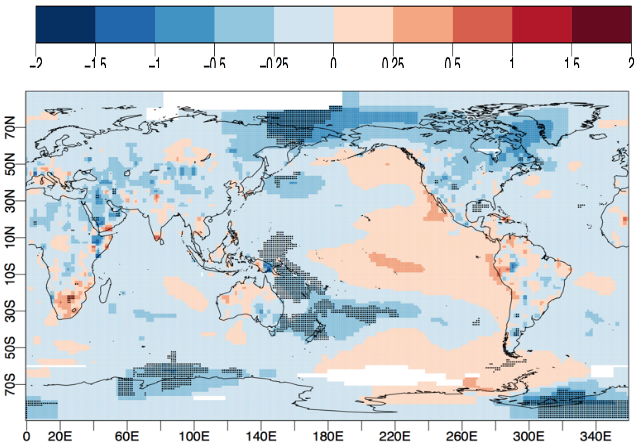


Observation

Surface temperature anomalies over forecast years 1-3 averaged after the last 3 major eruptions.

Surface temperature anomalies over forecast years 1-3 after the last 3 major eruptions. Anomalies are averaged over 3 start dates (and 5 members for the simulations).

Initialisation and volcanoes



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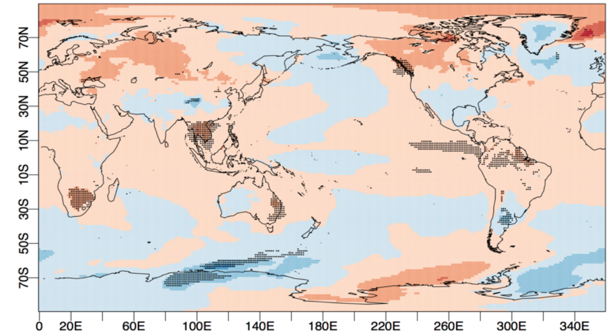
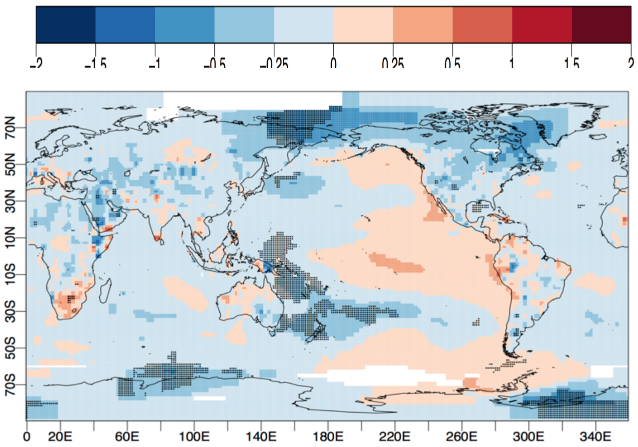


Initialisation and no volcanic forcing

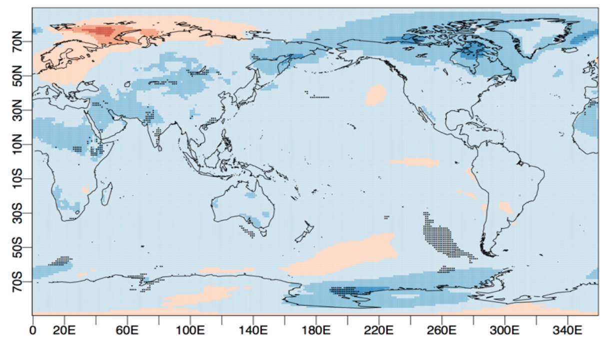
Surface temperature anomalies over forecast years 1-3 after the last 3 major eruptions. Anomalies are averaged over 3 start dates (and 5 members for the simulations).

Initialisation and volcanoes

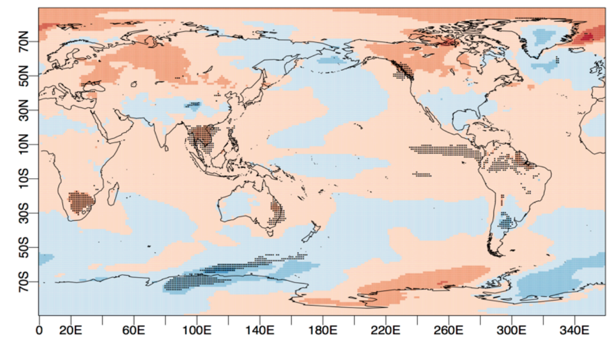


Observation

Surface temperature anomalies over forecast years 1-3 averaged after the last 3 major eruptions.



No initialisation and volcanic forcing



Initialisation and no volcanic forcing

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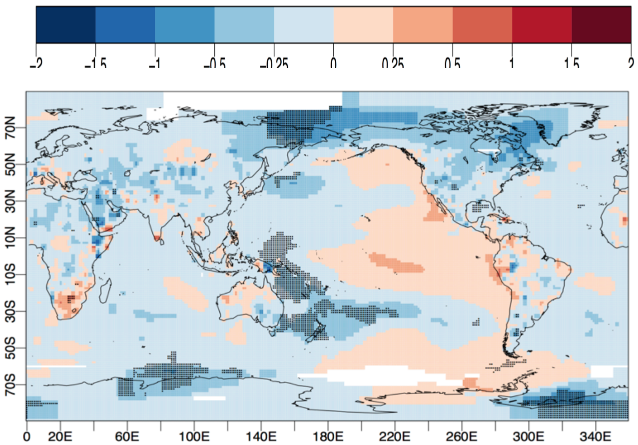
Initialisation and volcanoes



Observation

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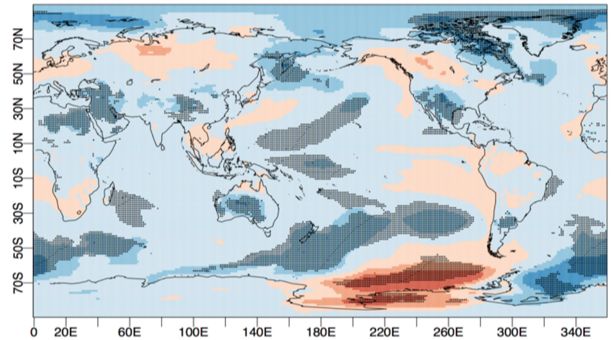
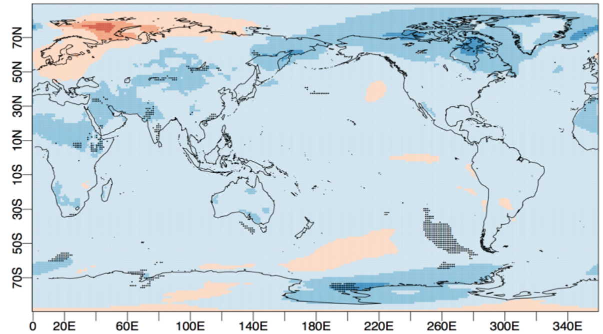
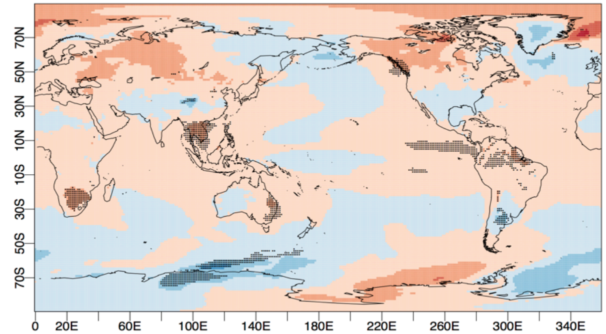


Initialisation and volcanic forcing



No initialisation and volcanic forcing



Initialisation and no volcanic forcing

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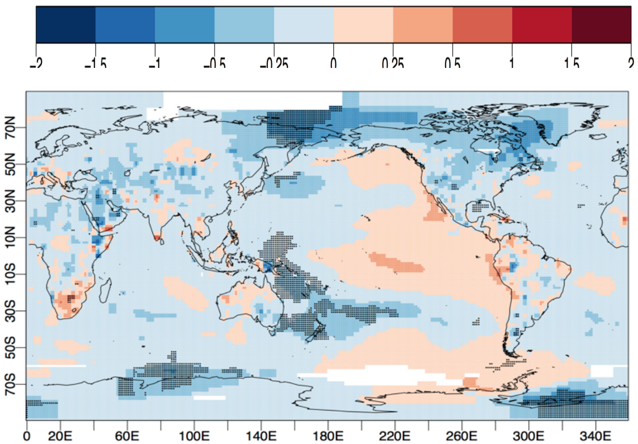
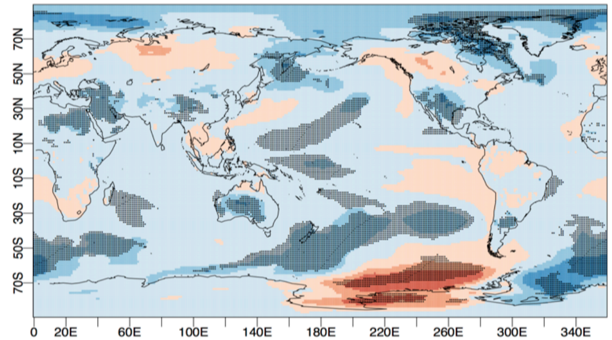
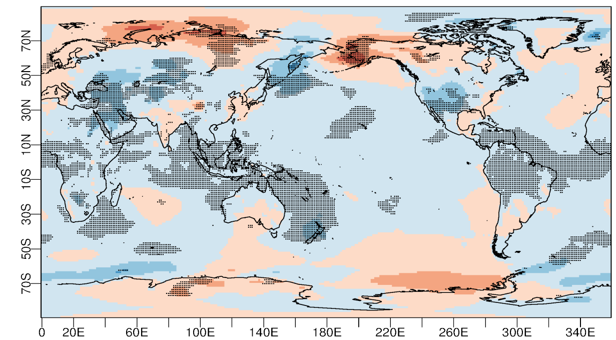
Initialisation and volcanoes



Observation

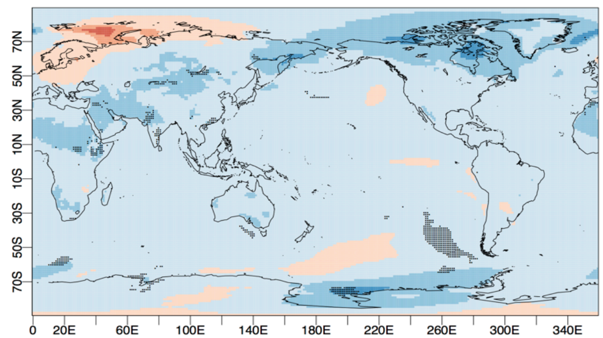


Initialisation and volcanic forcing

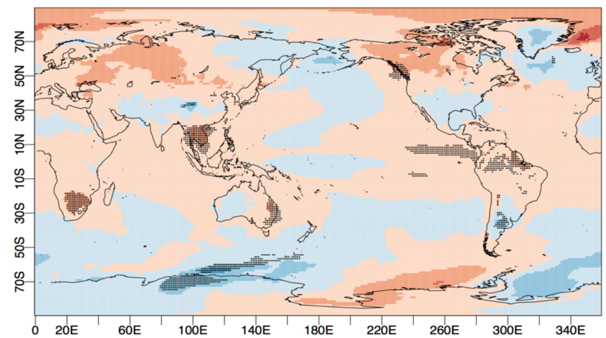


Initialisation and idealized volcanic forcing

Surface temperature anomalies over forecast years 1-3 averaged after the last 3 major eruptions.



No initialisation and volcanic forcing



Initialisation and no volcanic forcing

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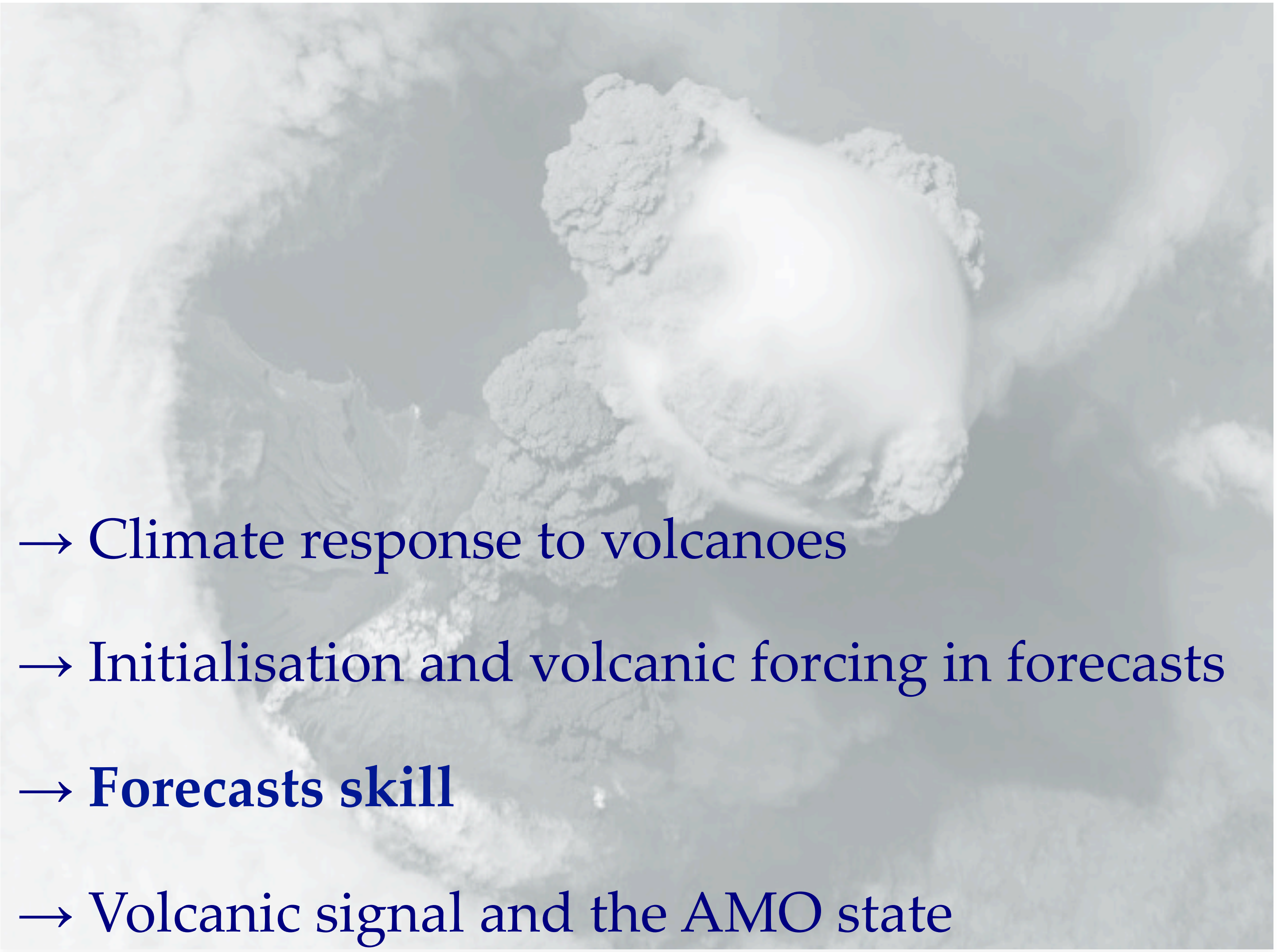


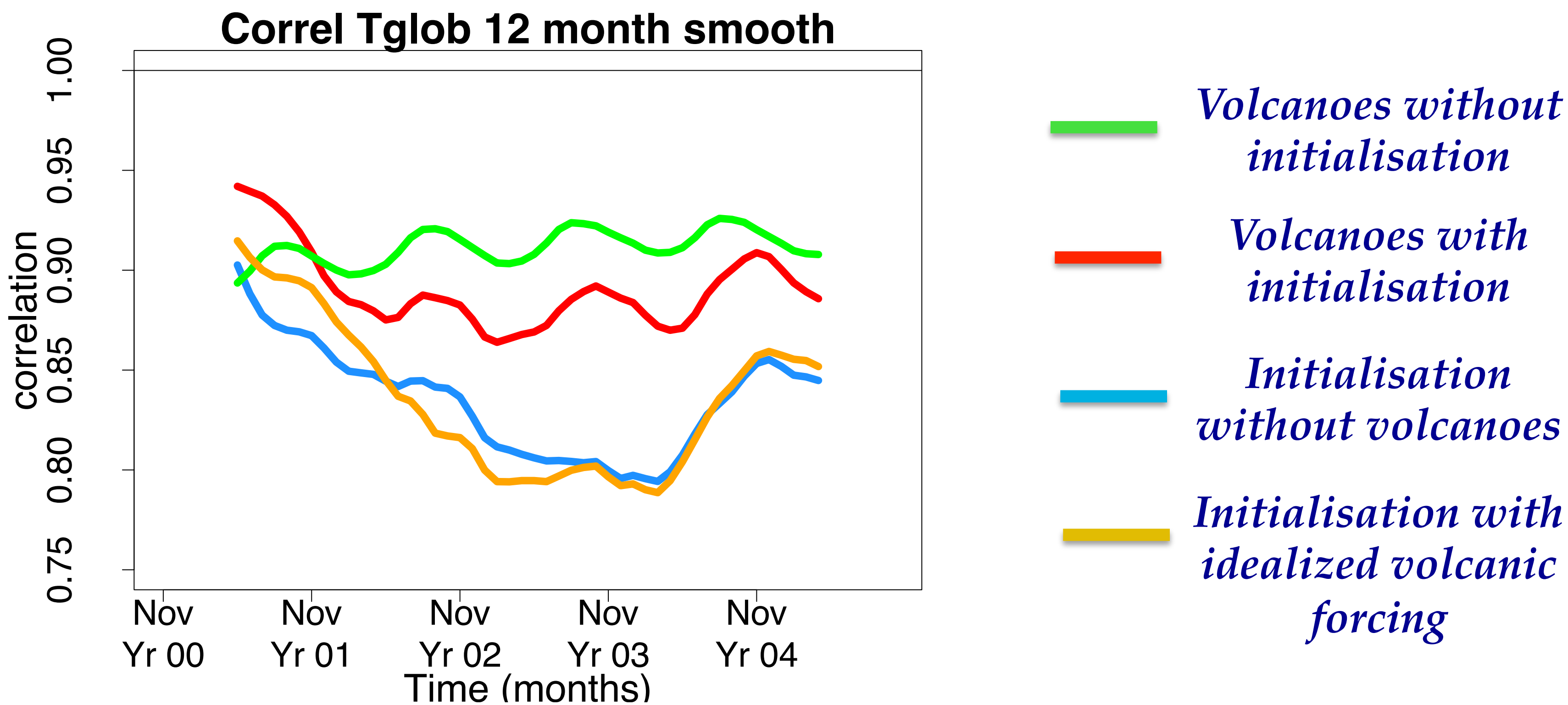
→ Climate response to volcanoes

→ Initialisation and volcanic forcing in forecasts

→ **Forecasts skill**

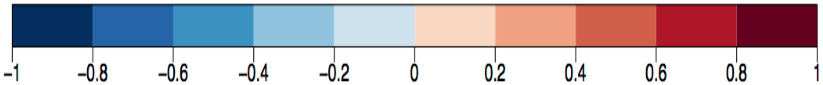
→ Volcanic signal and the AMO state

Correlation and RMSE

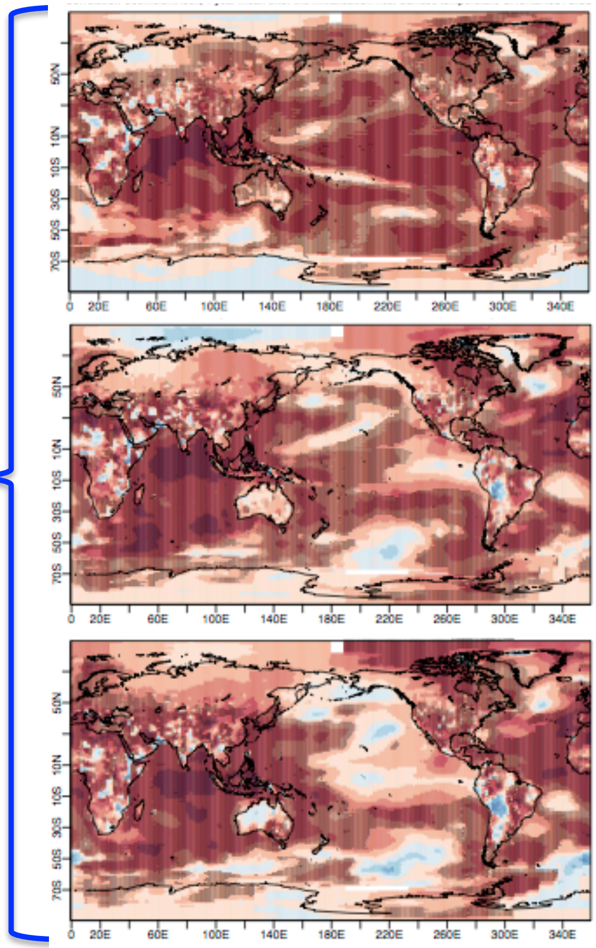


Correlation for 12 and 36 month smoothed running mean anomalies. Differences between hindcasts are not statistically significant.

Correlation and RMSE



Correlation with initialisation and volcanoes



Y 1

Y 1-3

Y 3-5

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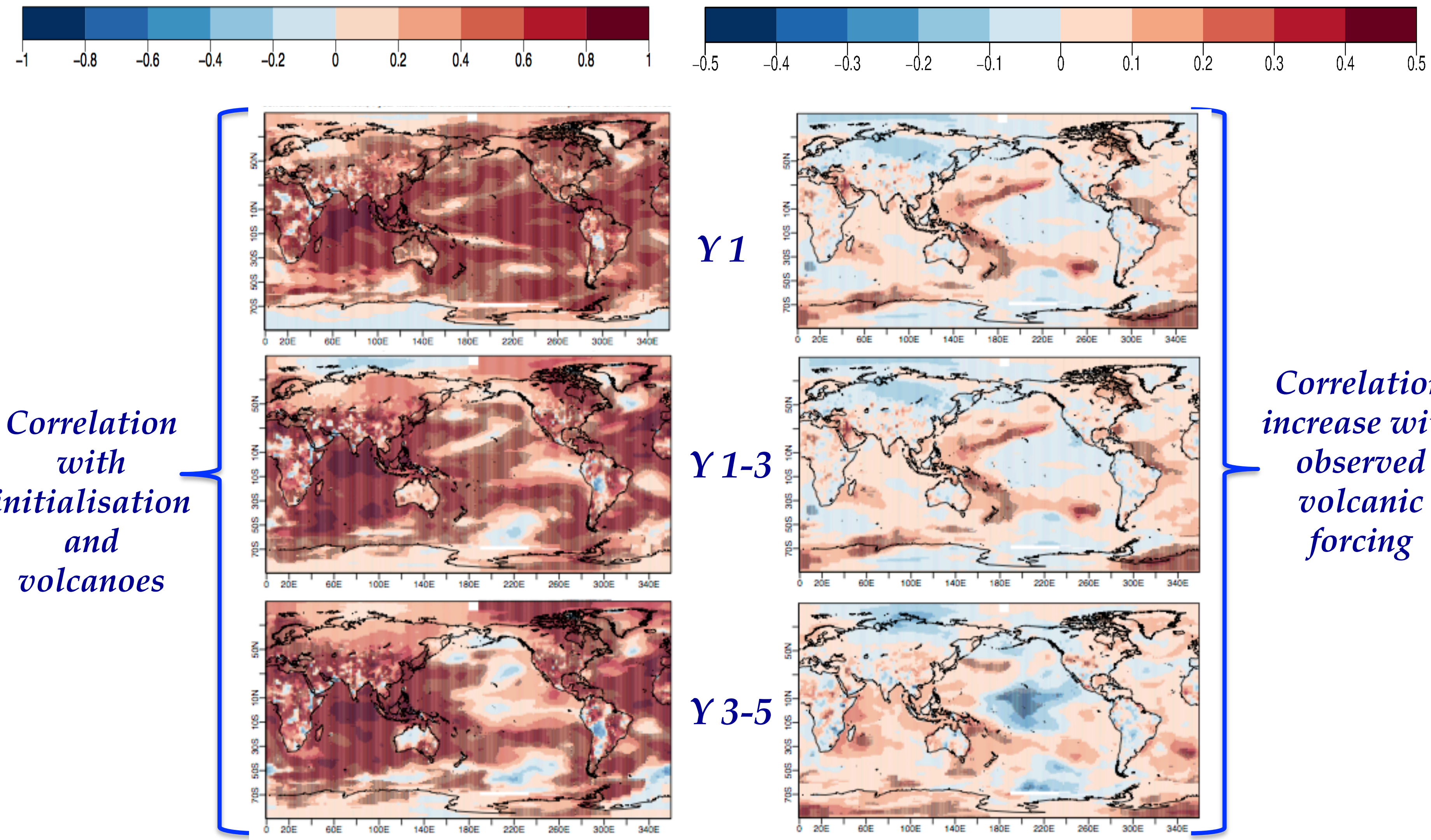
Correlation and RMSE

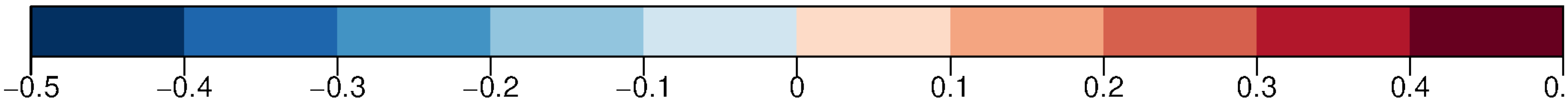
IC3

Correlation with initialisation and volcanoes

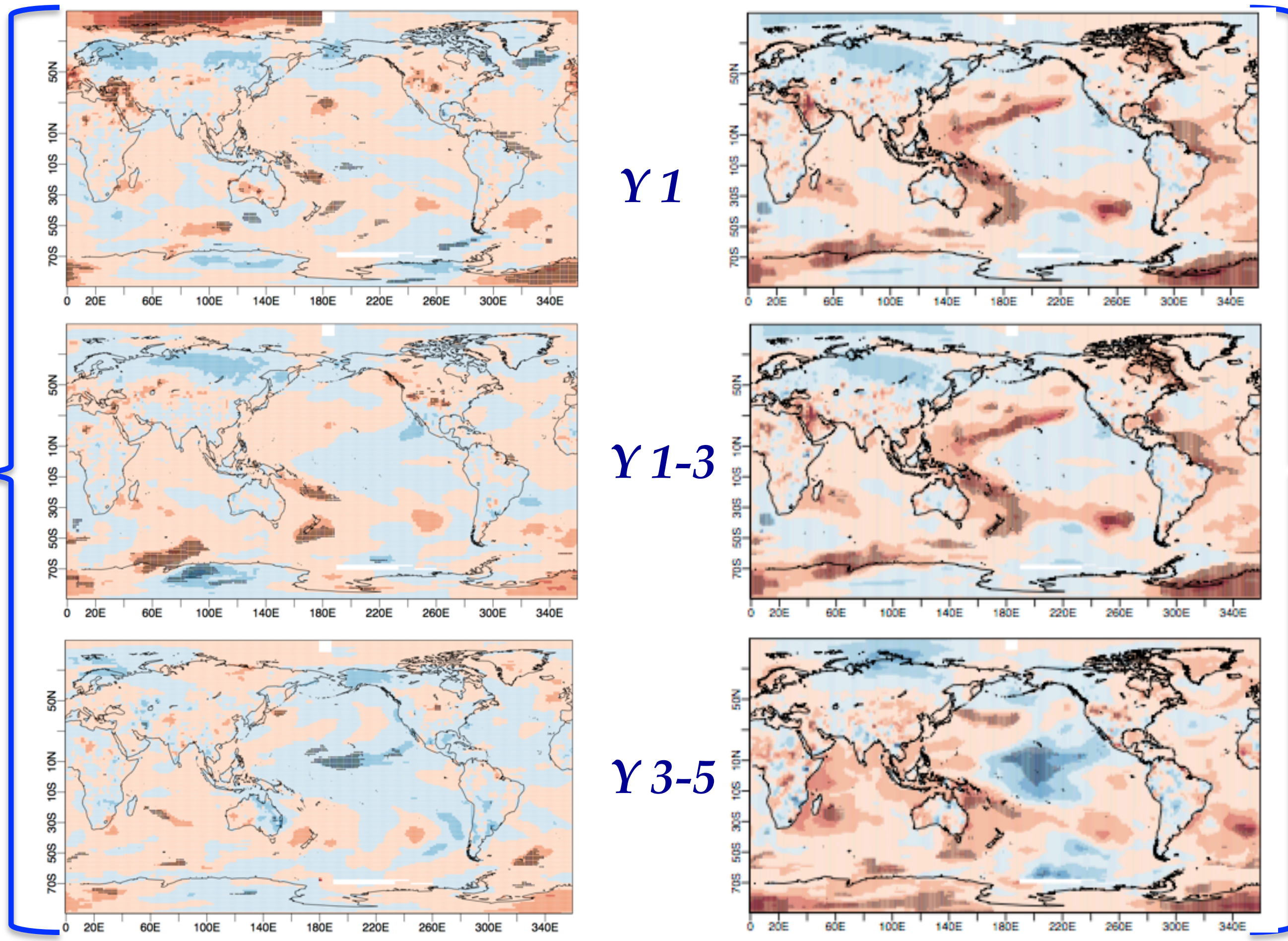


Correlation increase with observed volcanic forcing

Idealized forcing

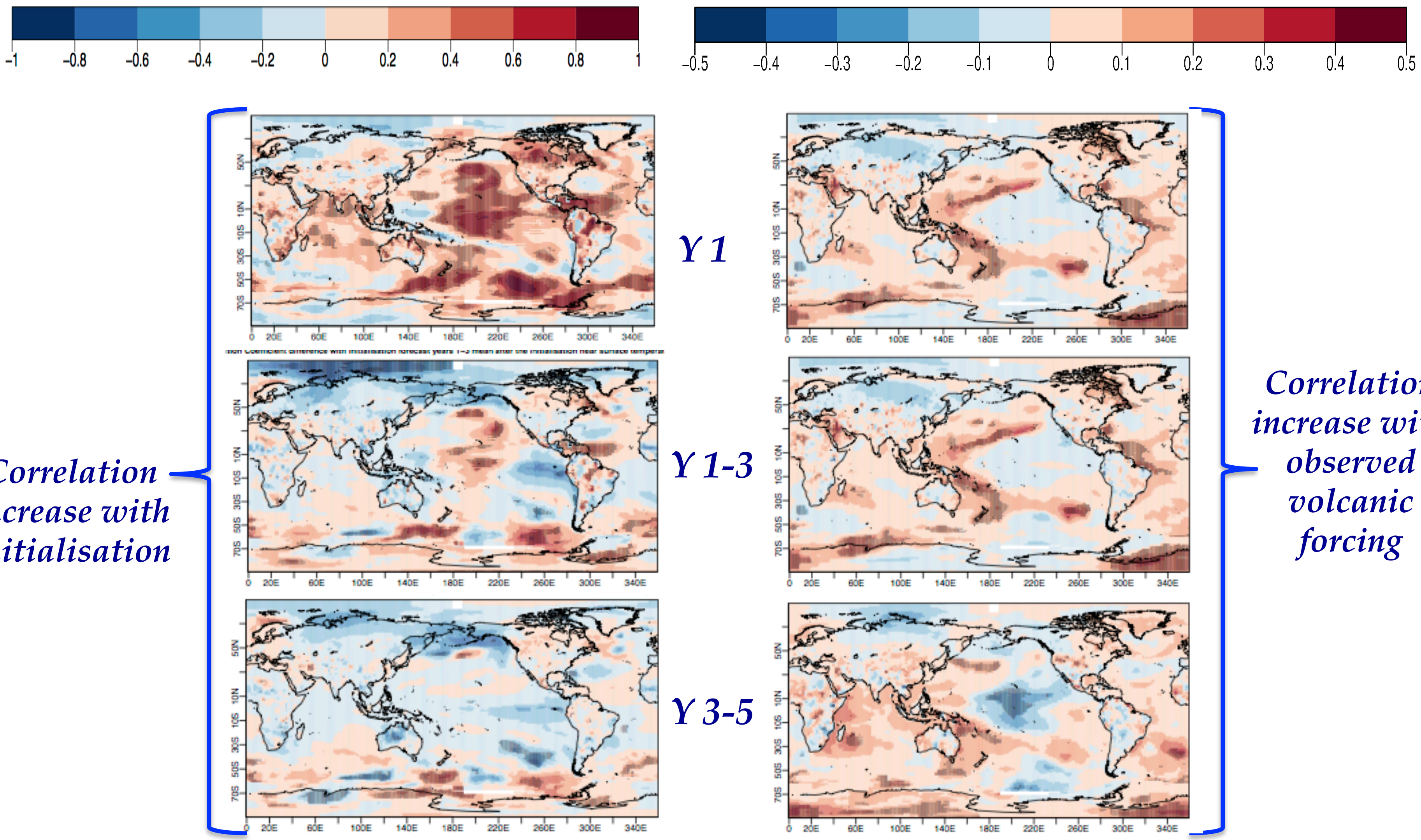


Correlation increase with idealized volcanic forcing



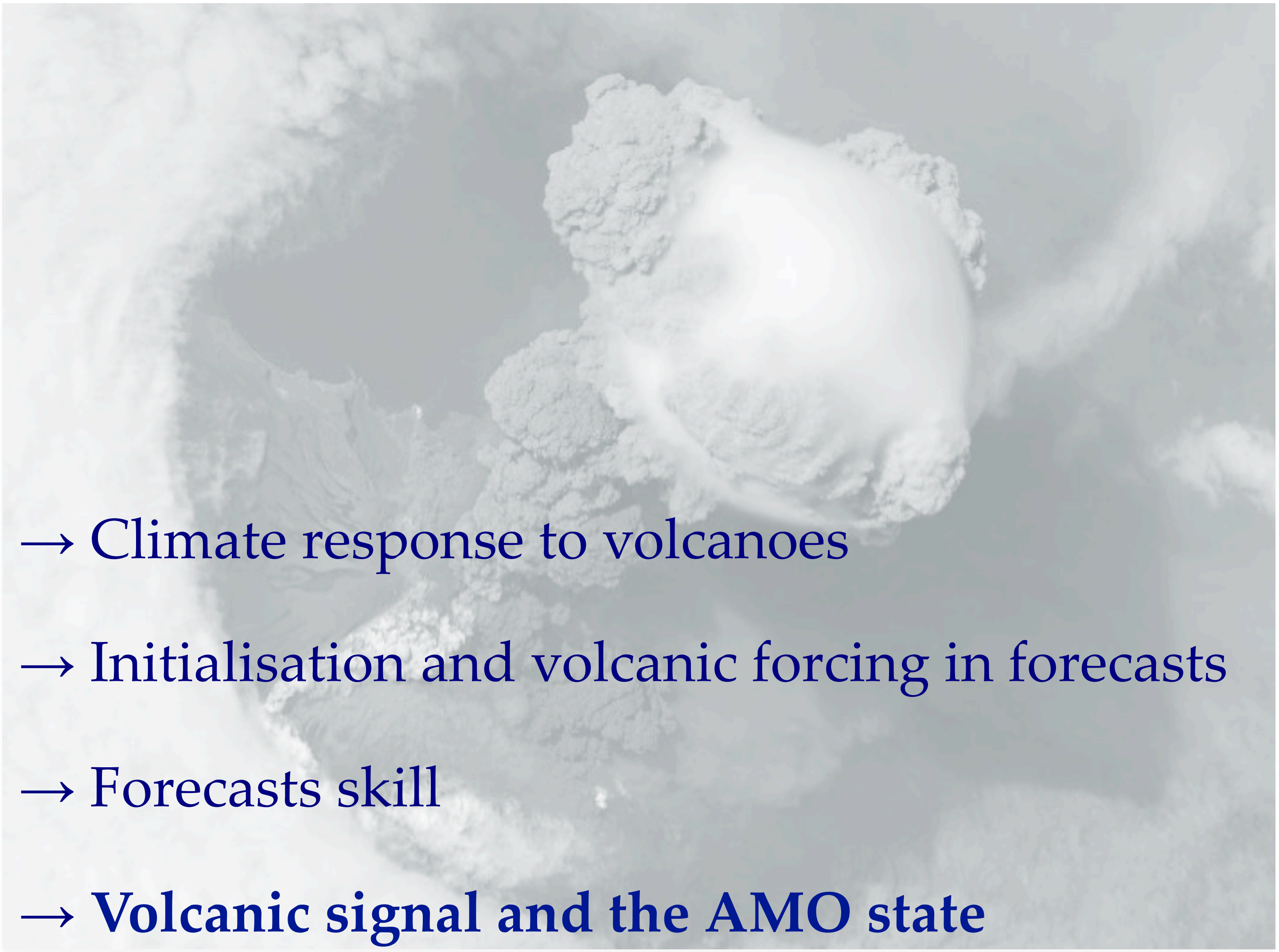
Correlation increase with observed volcanic forcing

Correlation and RMSE



Correlation increase with initialisation

Correlation increase with observed volcanic forcing



→ Climate response to volcanoes

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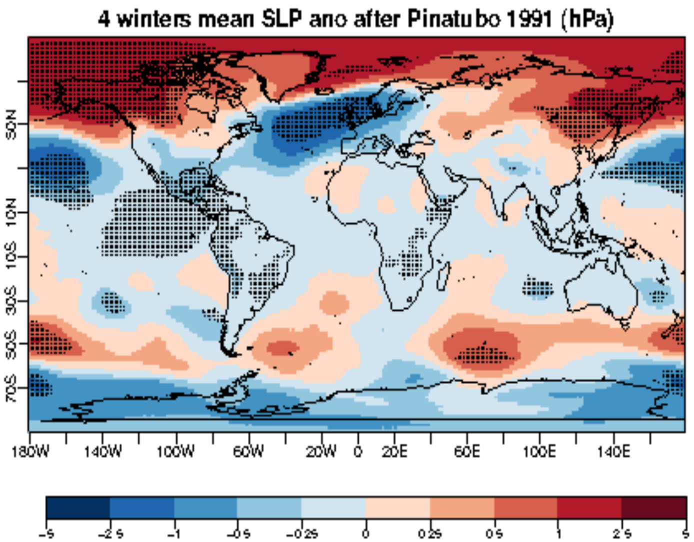
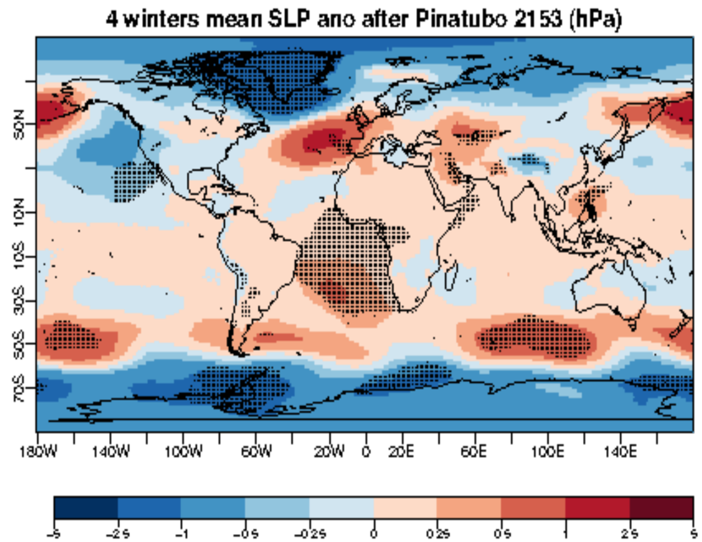
→ **Volcanic signal and the AMO state**

NAO and AMO

→ Simulating a Pinatubo under warm/cold phases of the AMO (Perfect model approach with the CNRM-CM5 model)



warm AMO



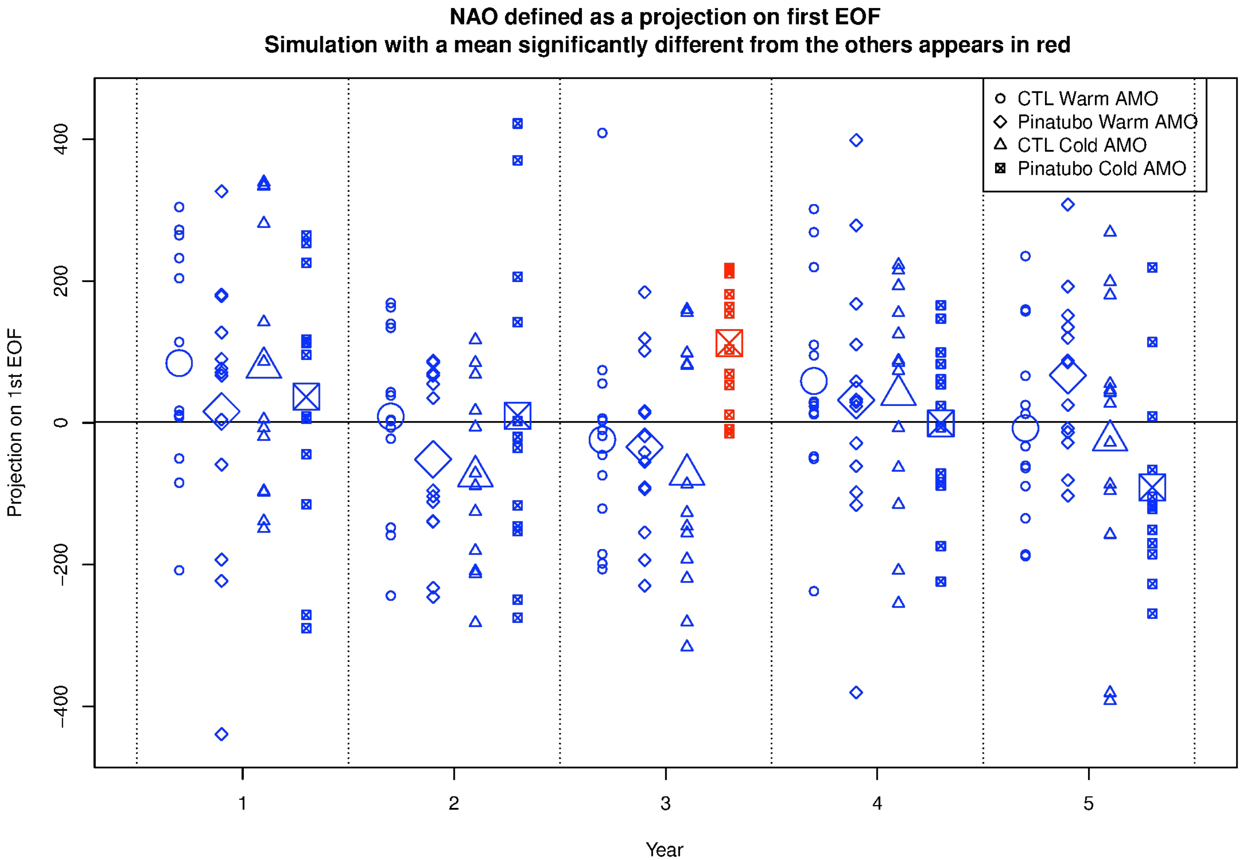
cold AMO

SLP anomaly (hPa) induced by a Pinatubo eruption

→ NAO+ signal after eruptions occurring when the AMO is negative

NAO and AMO

→ Simulating a Pinatubo under warm/cold phases of the AMO (Perfect model approach with the CNRM-CM5 model)



Significant NAO+ signal the third winter after a Pinatubo eruption under a cold AMO

Conclusion

→ Last major eruptions induced a strong cooling over the tropics and the Northern continent that was partly overwhelmed by internal variability.

→ Evaluating the performances of climate forecast systems cannot be done without considering large eruptions that occurred during the last decades.

→ The EC-Earth historical simulation has higher skill than hindcasts.

→ Volcanic forcing in hindcasts is associated to an increase of skill for surface temperature in Western Pacific, tropical Atlantic and Indian Ocean.

→ A real-time forecast of the next volcanic eruption require the design of an idealized forcing.

→ EC-Earth has no skill to predict the NAO, even after volcanic eruptions.

→ The CNRM-CM5 model simulates a NAO+ response the third winter following a Pinatubo eruption when the AMO is cold.

Thank you

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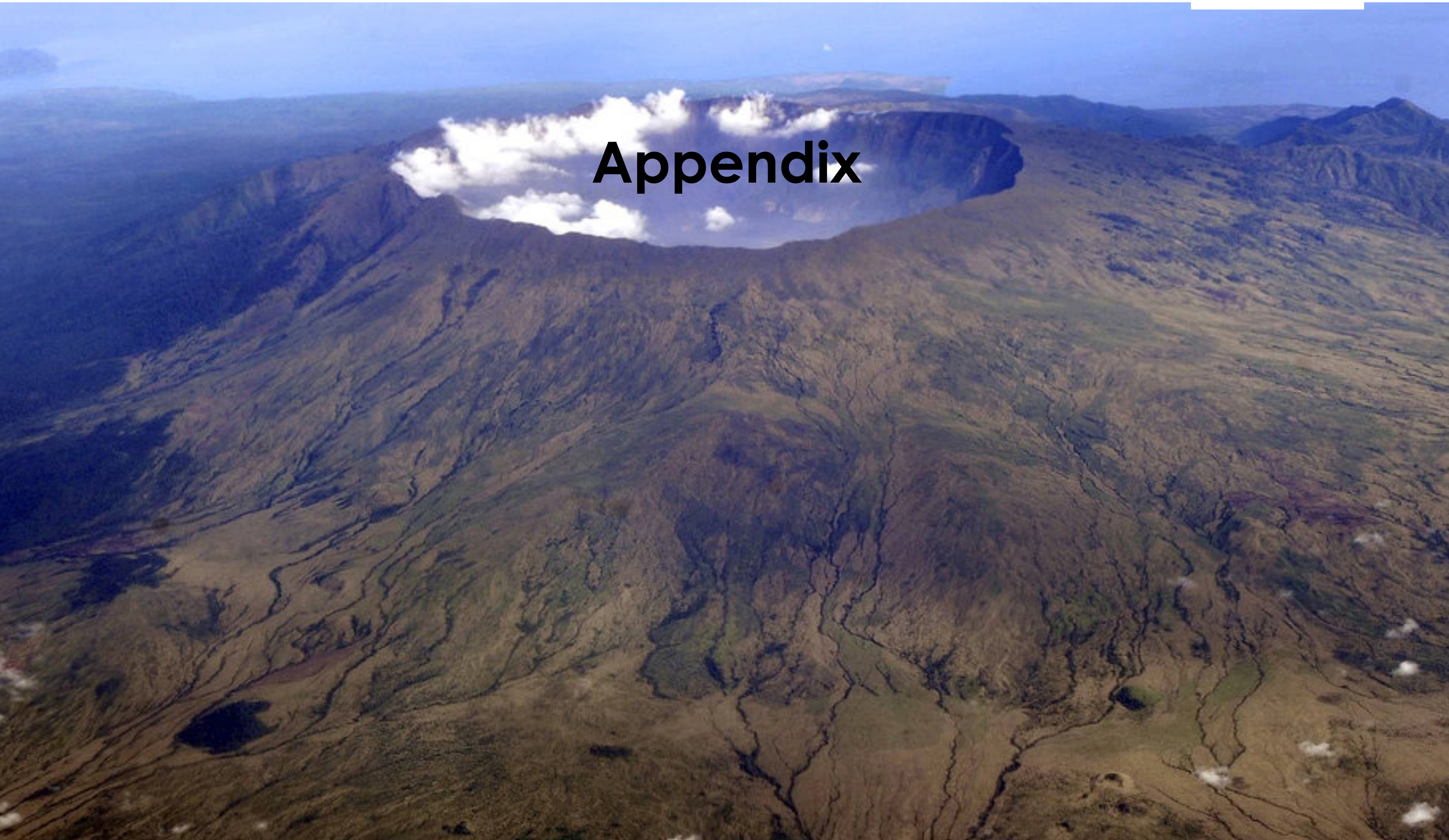
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Appendix



Winter response

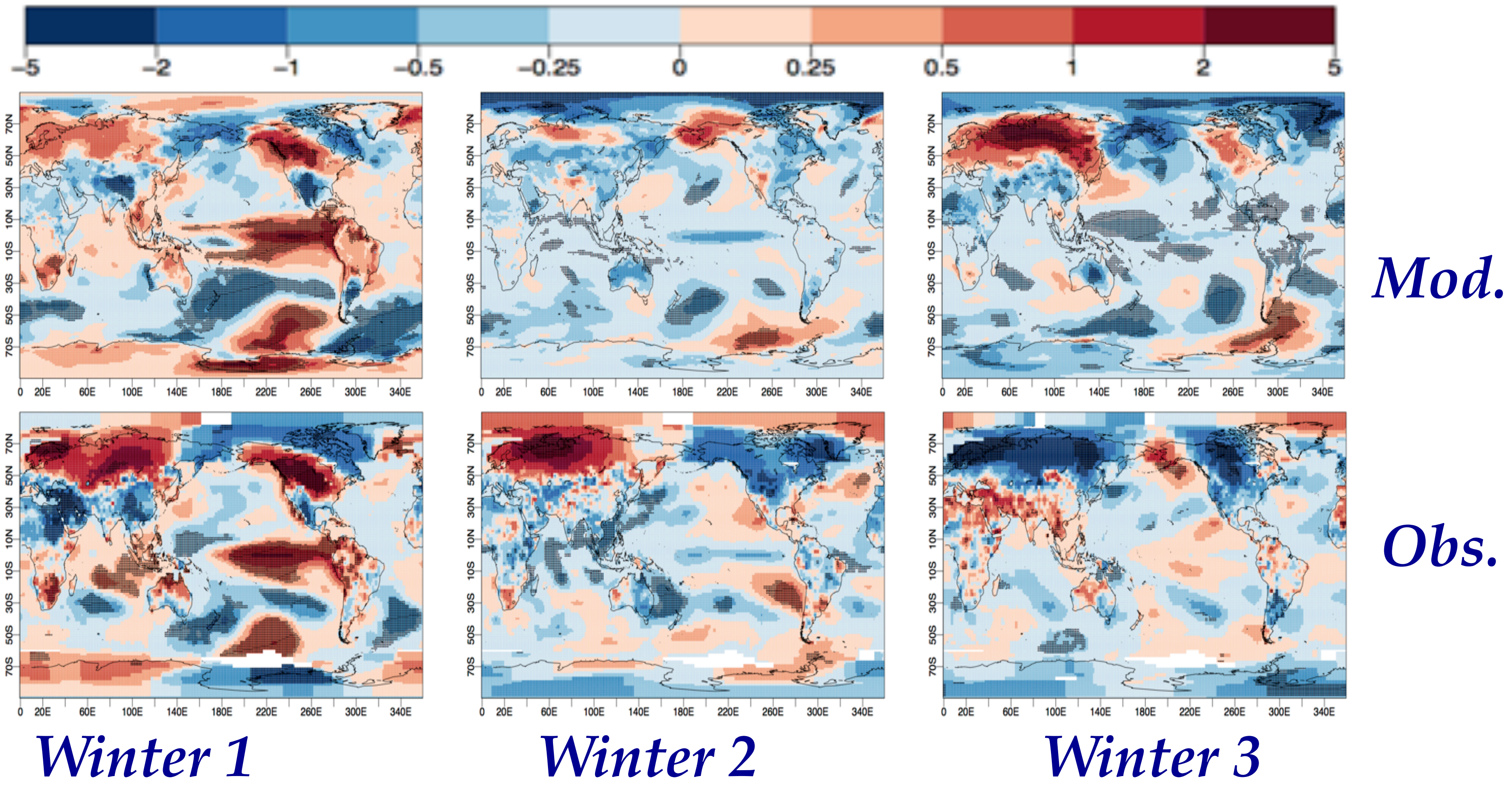
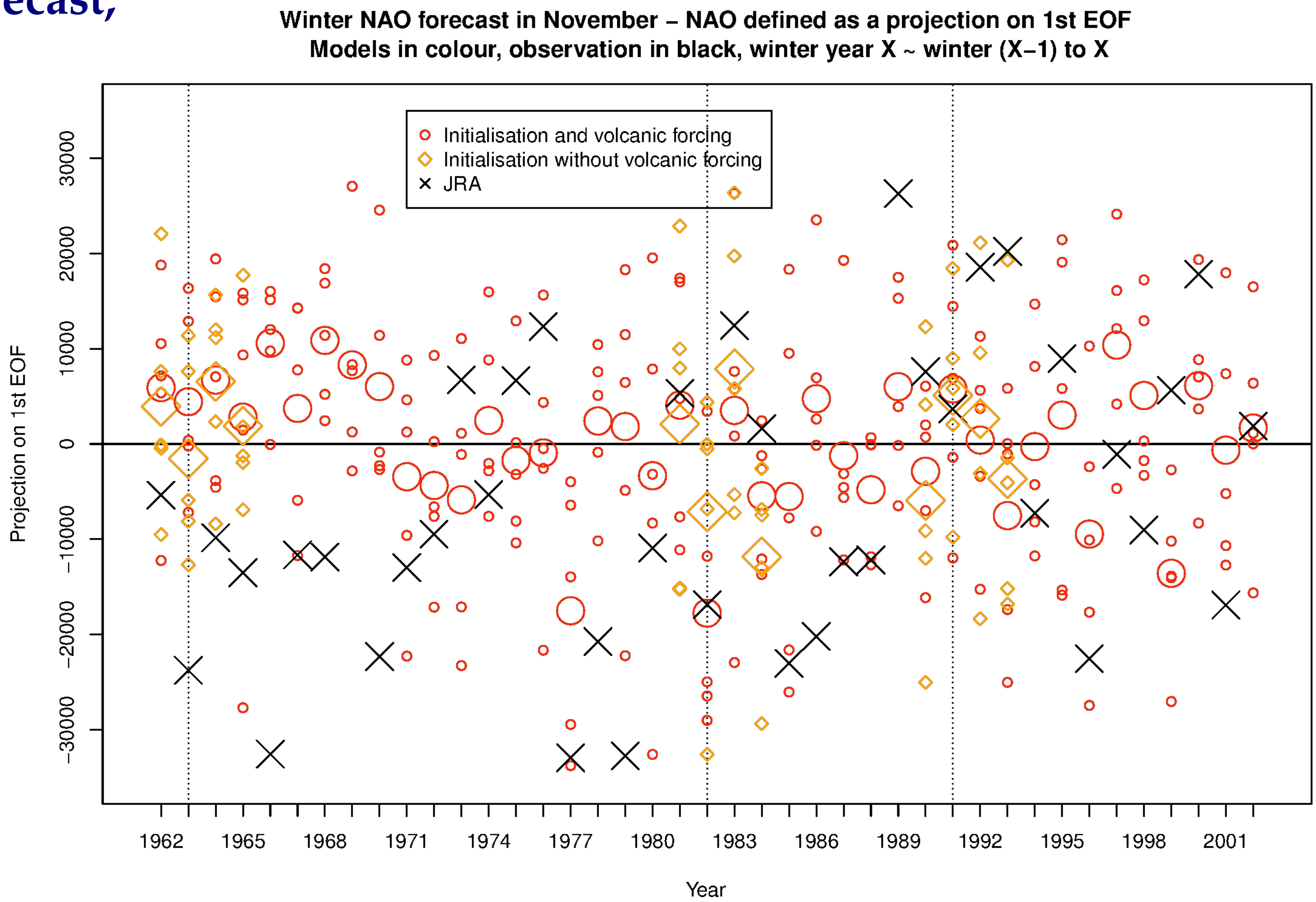


Figure 5: Winter surface temperature anomalies after the last 3 major eruptions. Anomalies are averaged over 3 dates (and 5 members for the simulations). Top: forecast; bottom: observations

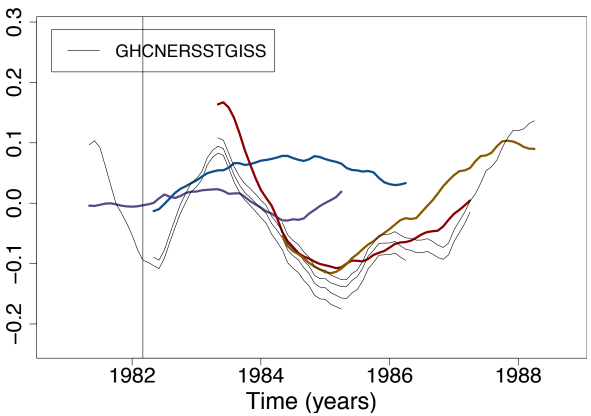
Winter response

→ **NAO forecast, winter 1, no skill! (R~0.1)**

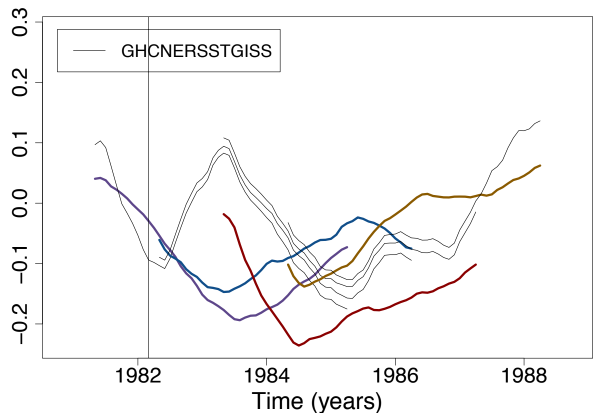


Initialisation and volcanoes

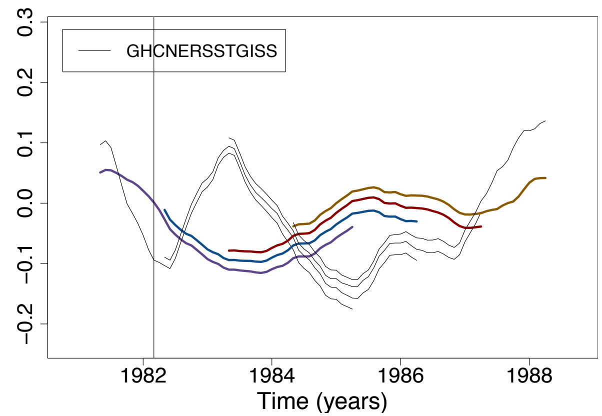
El Chichón



Initialisation without volcanoes



Initialisation with volcanoes

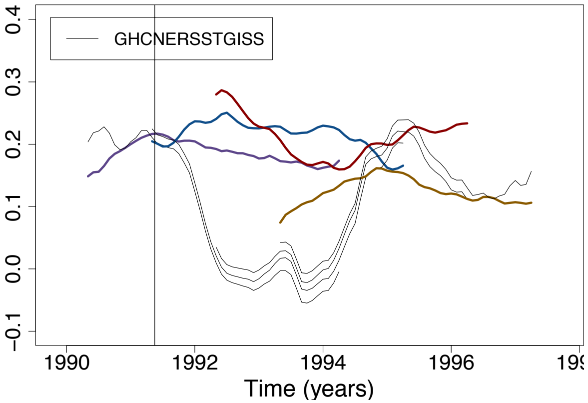


Volcanoes without initialisation

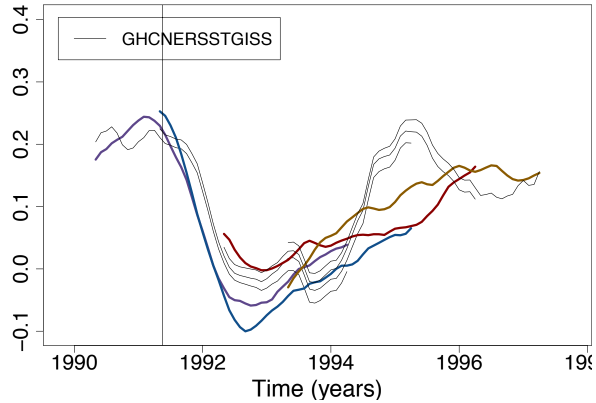
Surface temperature anomalies forecast for 4 different startdates around the El Chichón eruption (blue and purple start before the eruption; red and yellow start after the eruption). Hindcasts start in November. Observations anomalies (black) are computed with climatologies varying along the forecast time, data from ERSST and GHCN (GISS). Anomalies are smoothed with a 12-month running mean.

Initialisation and volcanoes

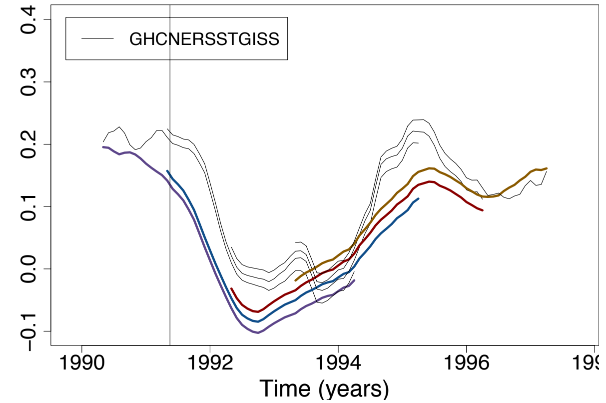
Pinatubo



Initialisation without volcanoes



Initialisation with volcanoes

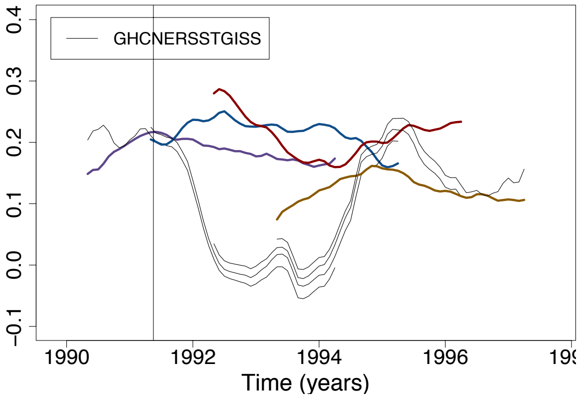


Volcanoes without initialisation

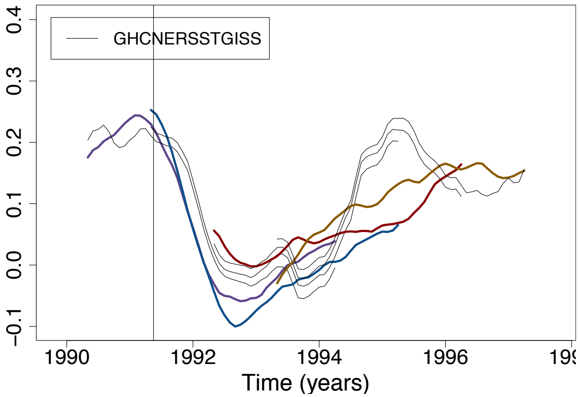
Surface temperature anomalies forecast for 4 different startdates around the Pinatubo eruption (blue and purple start before the eruption; red and yellow start after the eruption). Hindcasts start in November. Anomalies observations (black) are computed with climatologies varying along the forecast time, data from ERSST and GHCN (GISS). Anomalies are smoothed with a 12-month running mean.

Initialisation and volcanoes

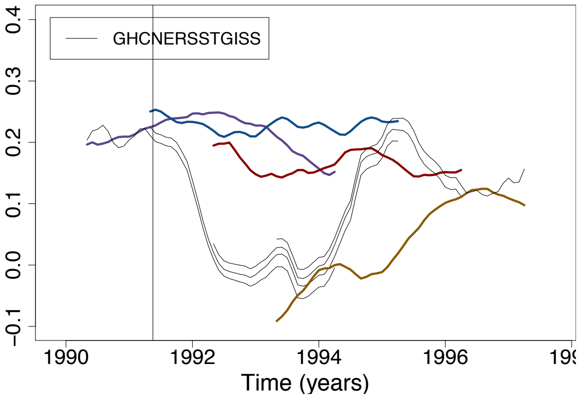
Pinatubo



Initialisation without volcanoes



Initialisation with volcanoes

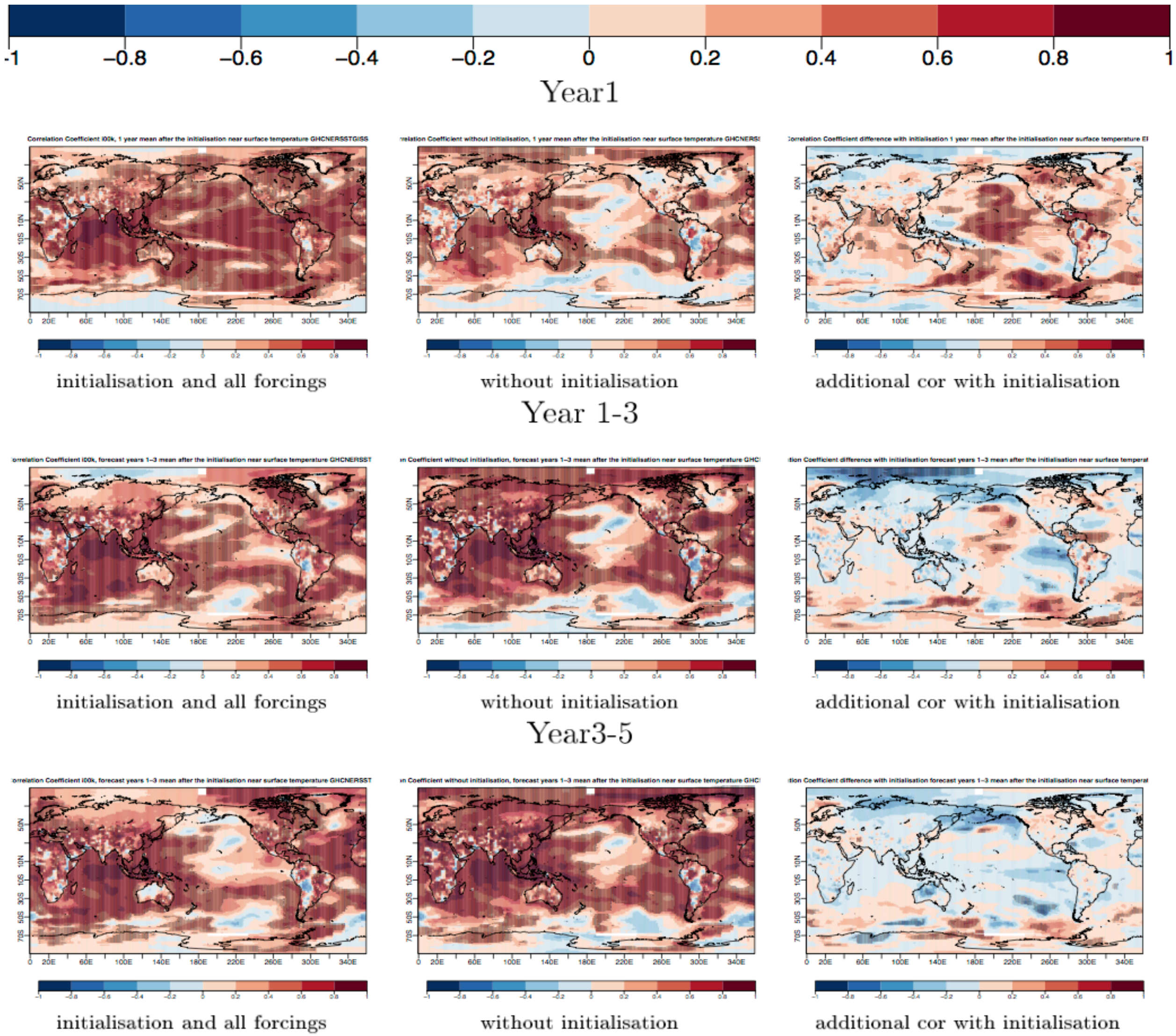


Initialisation with idealized volcanoes

Surface temperature anomalies forecast for 4 different startdates around the Pinatubo eruption (blue and purple start before the eruption; red and yellow start after the eruption). Hindcasts start in November. Anomalies observations (black) are computed with climatologies varying along the forecast time, data from ERSST and GHCN (GISS). Anomalies are smoothed with a 12-month running mean. Idealized forcing is computed as the current stratospheric aerosol load at the startdate decreasing toward "background level" after a one year exponential decay.

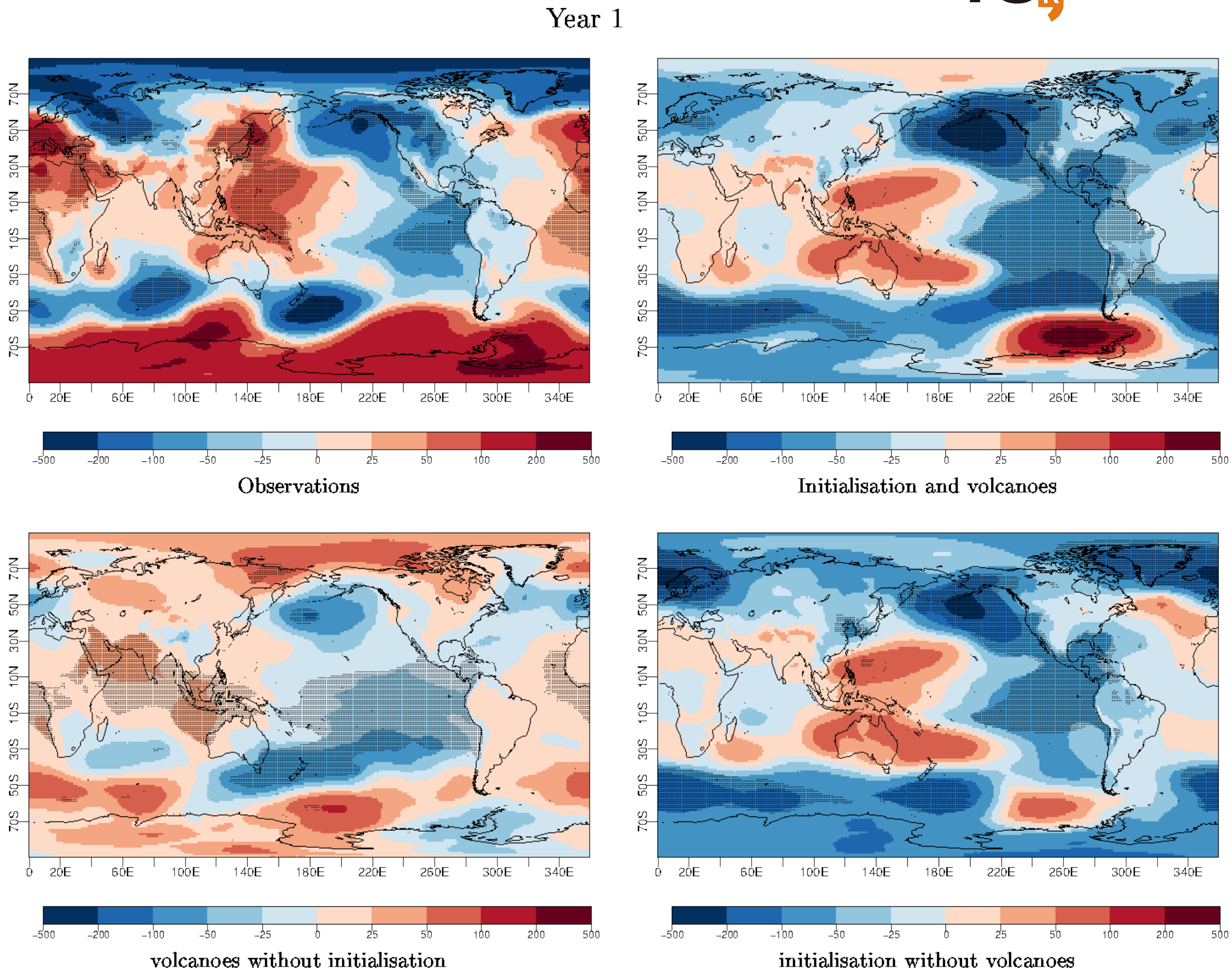
Appendix

→ **Skill increase with initialisation**

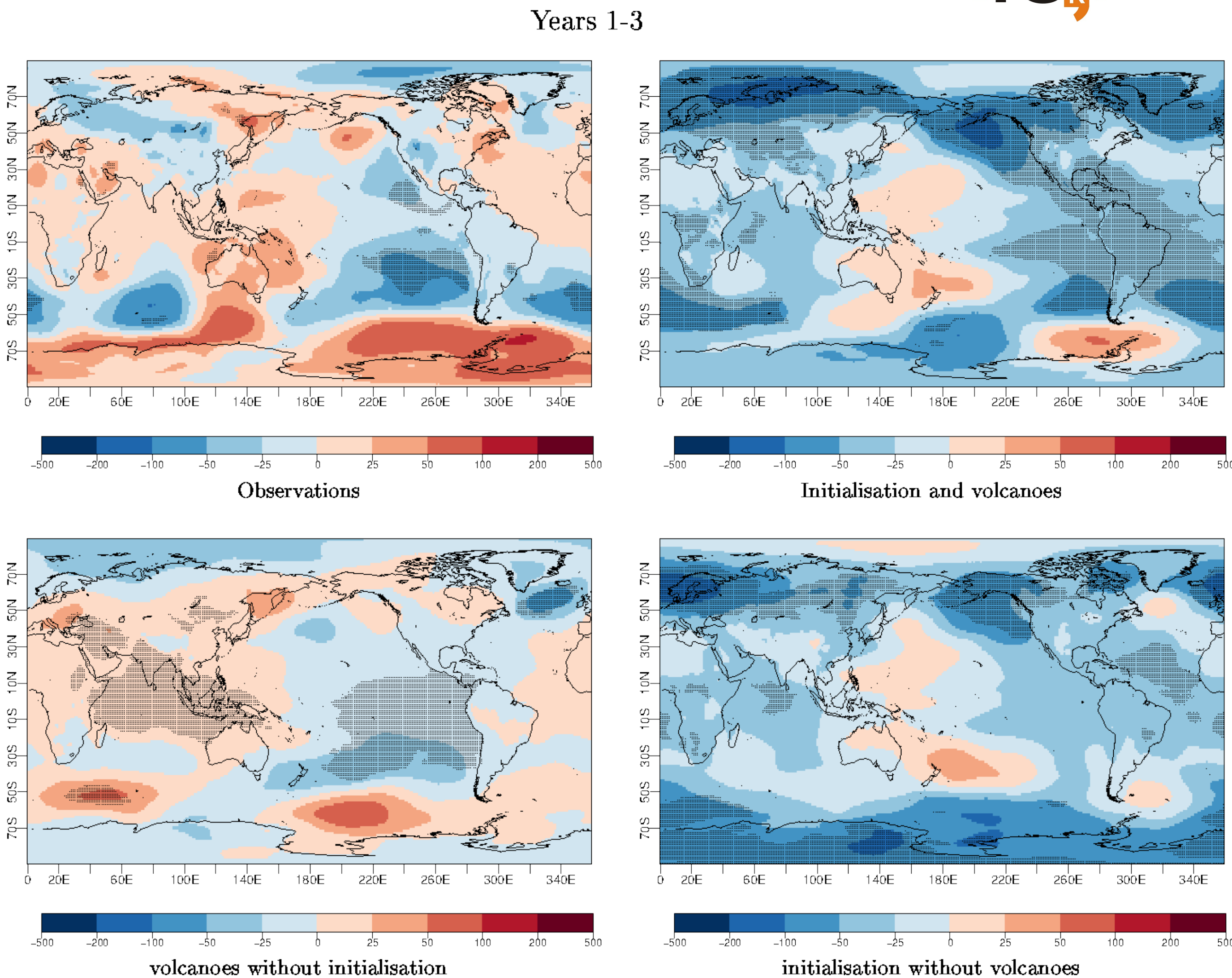


Appendix

→ **First year pressure anomalies**



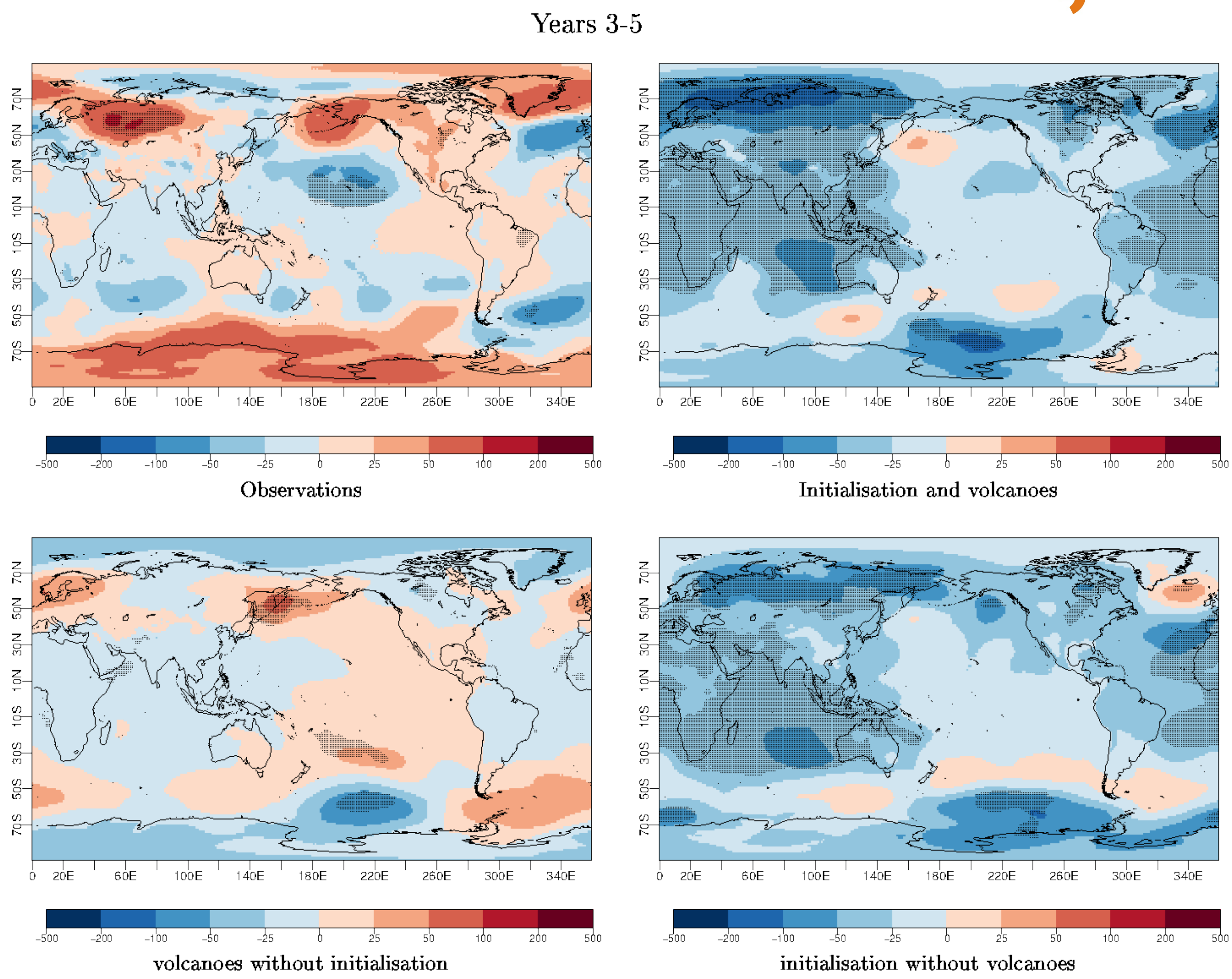
Appendix



→ Years 1-3 pressure anomalies

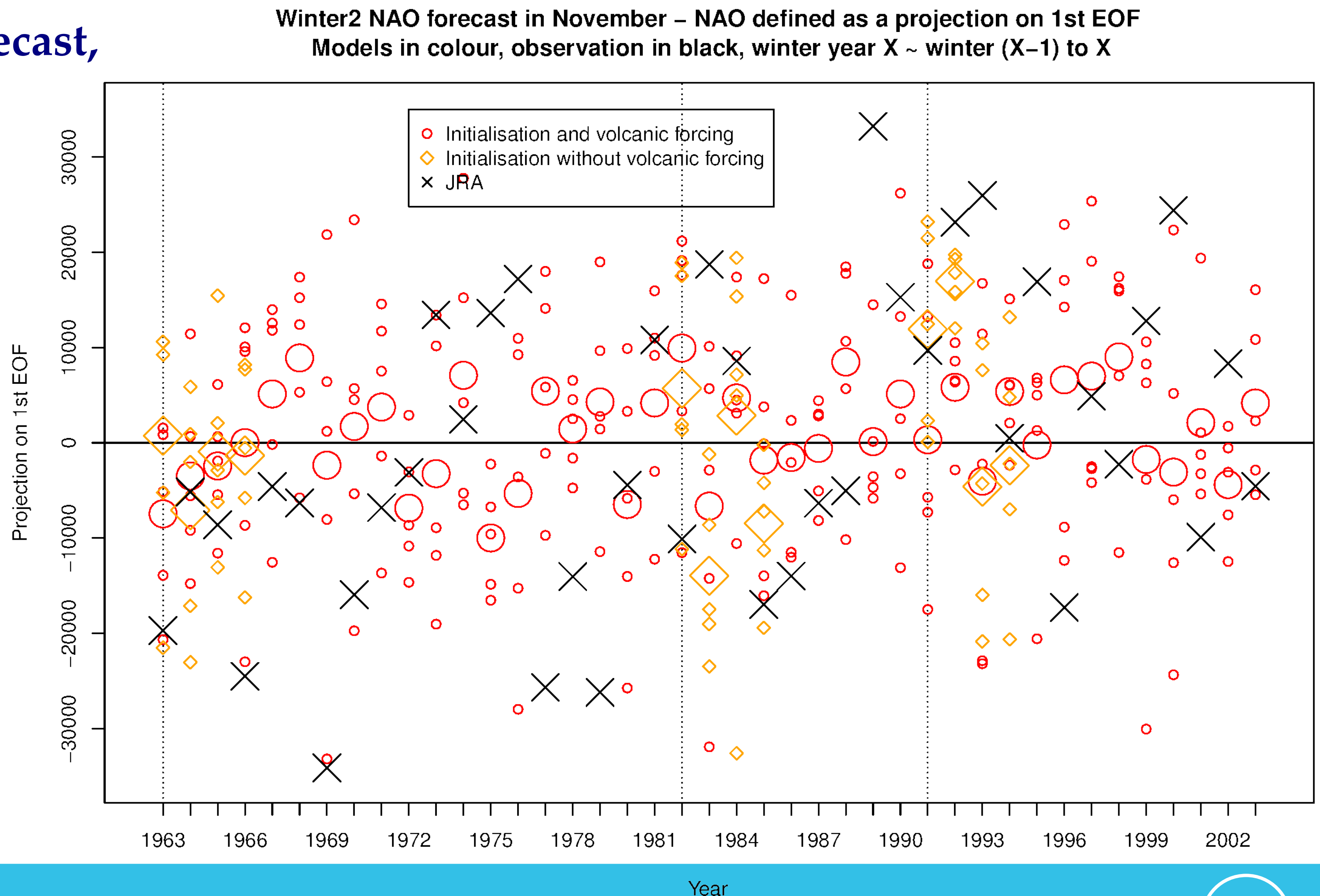
Appendix

→ Years 3-5 pressure anomalies



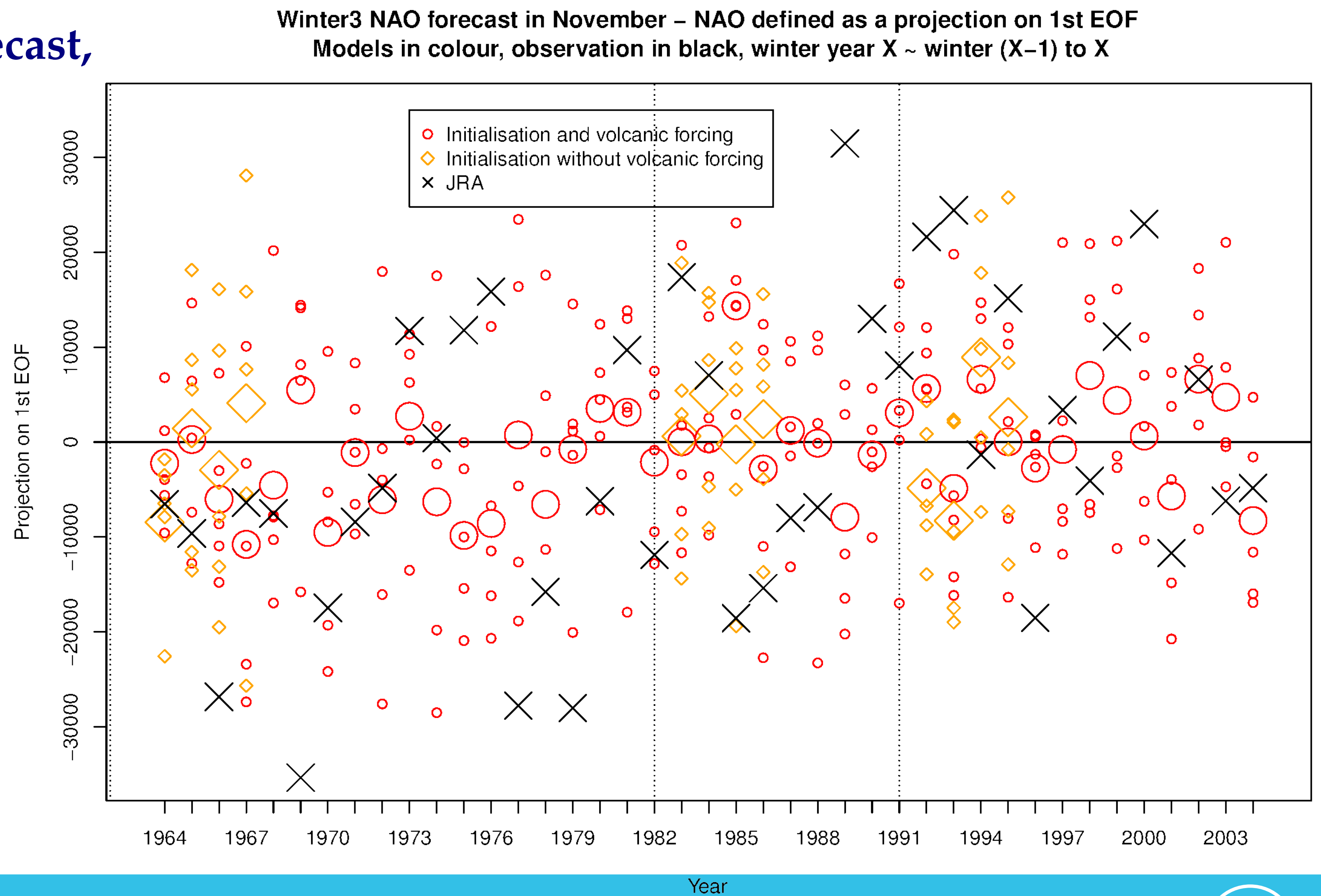
Appendix

→ **NAO forecast, winter 2**



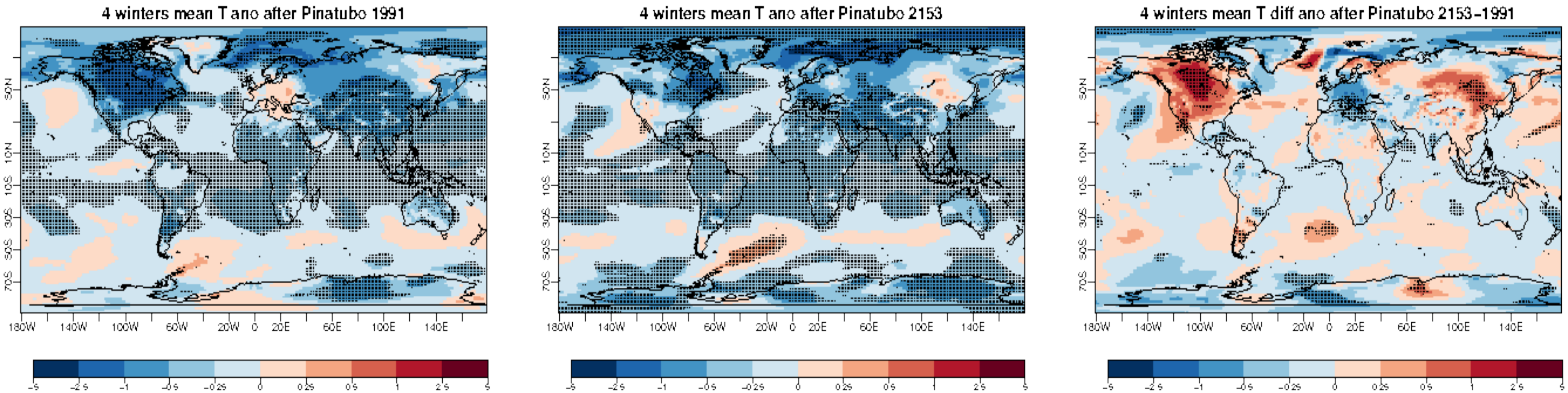
Appendix

→ **NAO forecast, winter 3**



NAO and AMO

→ Simulating a Pinatubo under warm/cold phases of the AMO (Perfect model approach with the CNRM-CM5 model)



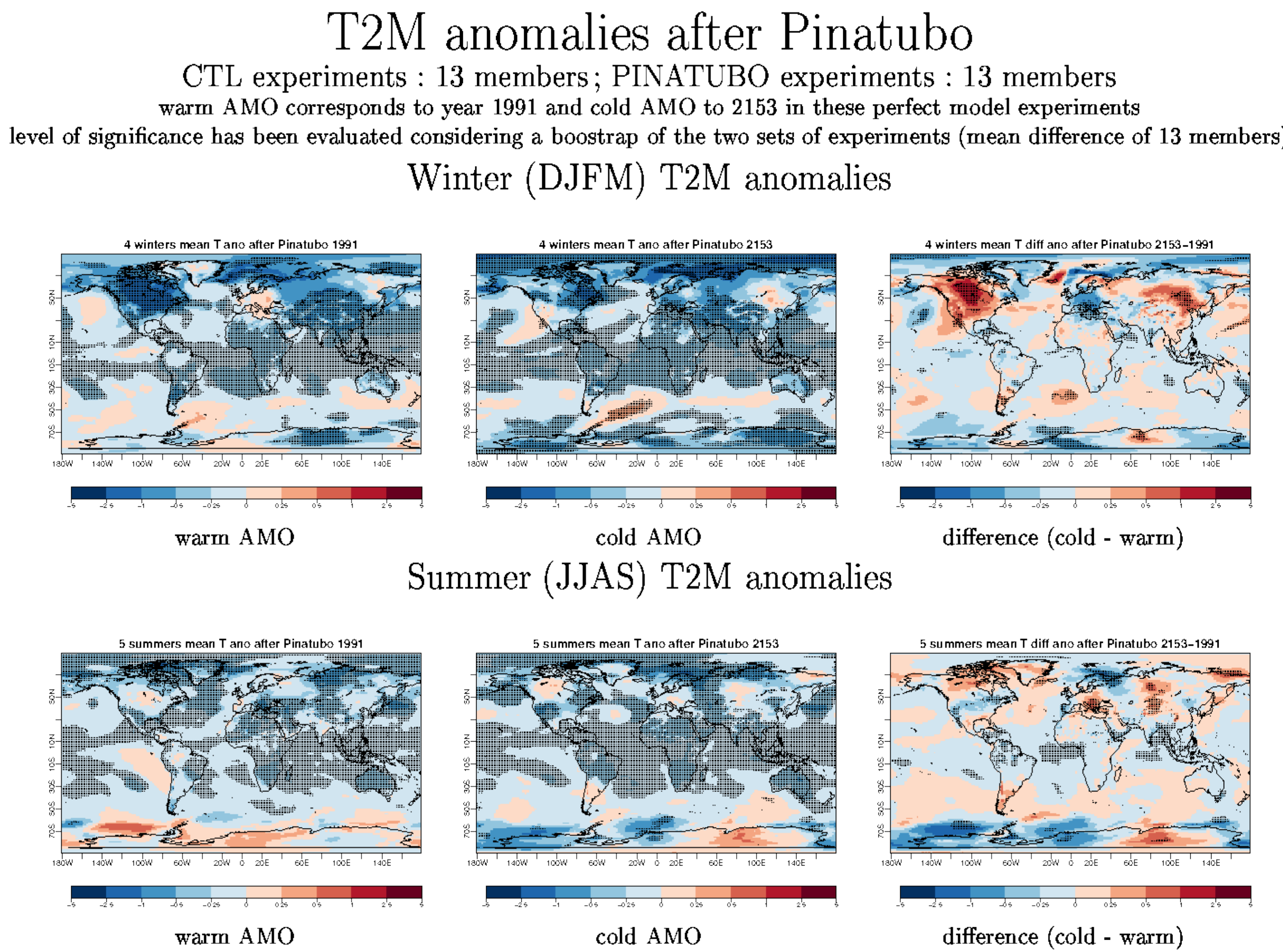
warm AMO cold AMO difference (cold - warm)

T anomaly (°C) induced by a Pinatubo eruption

→ T response to volcanic eruption differs widely according to the AMO state

Appendix

→ Winter temperature anomalies, AMO sensitivities experiments with CNRM-CM5



Appendix

→ **Winter SLP anomalies, AMO sensitivities experiments with CNRM-CM5**

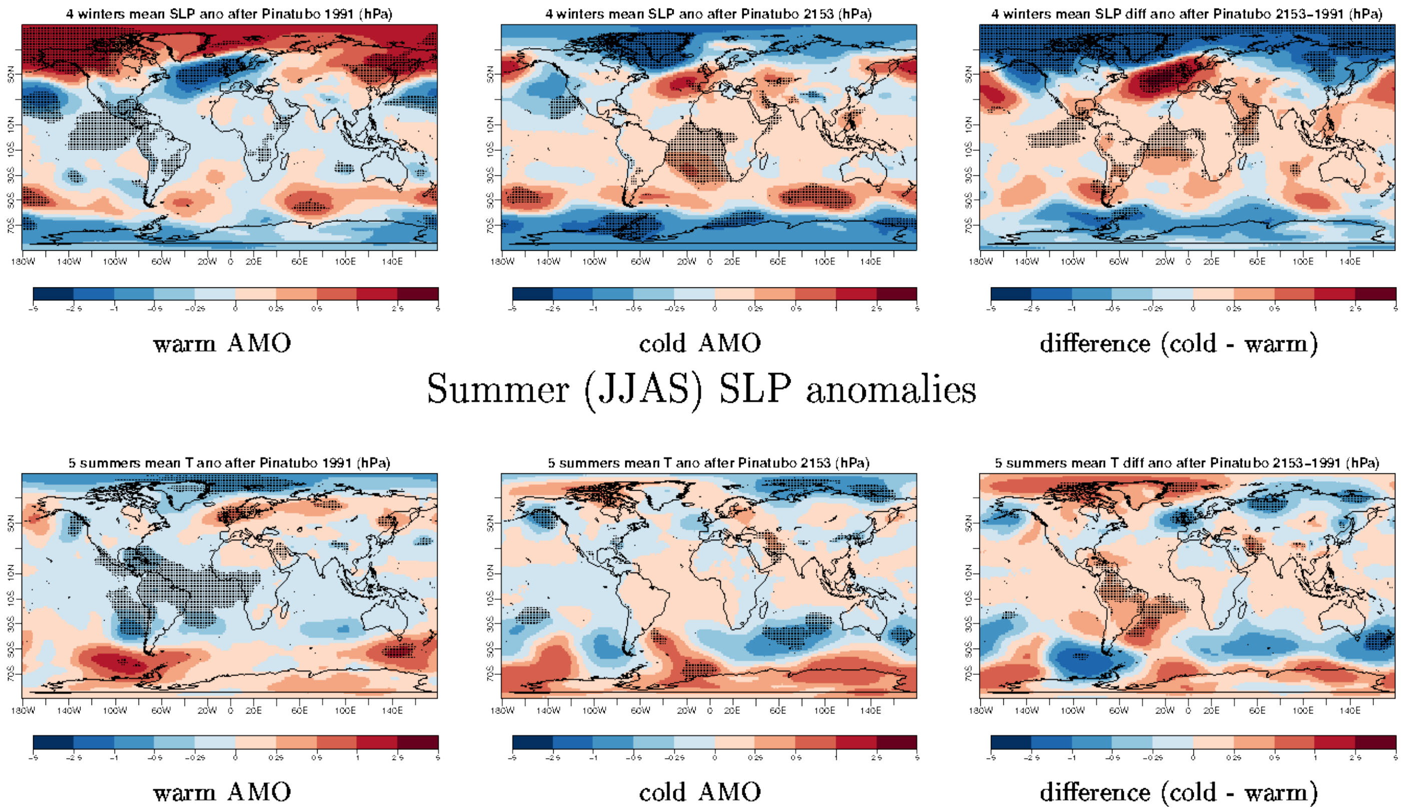
SLP anomalies after Pinatubo

CTL experiments : 13 members; PINATUBO experiments : 13 members

warm AMO corresponds to year 1991 and cold AMO to 2153 in these perfect model experiments

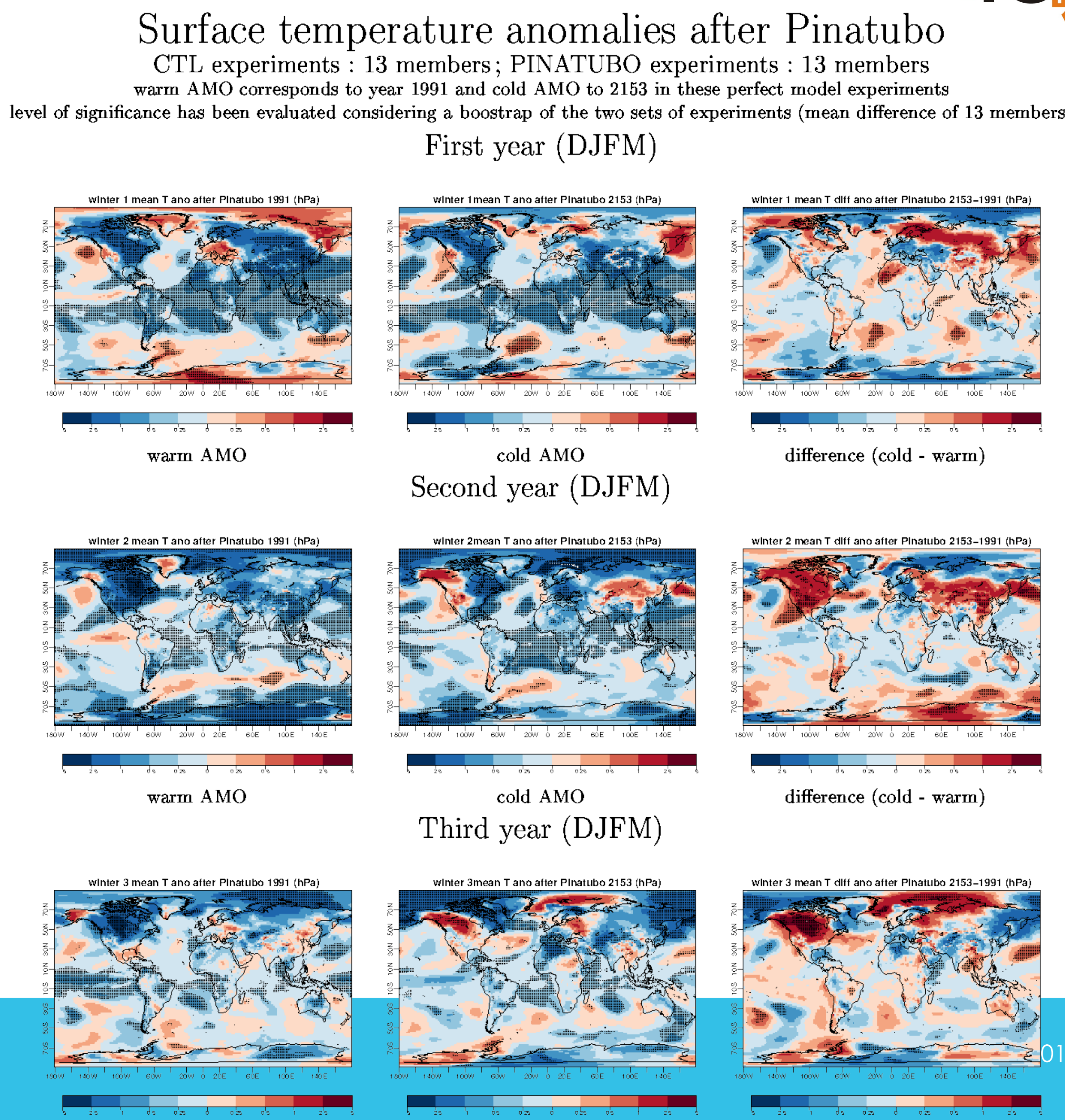
level of significance has been computed from a t-test considering a boostrap resampling (mean difference of 13 members) of the two sets of experiments

Winter (DJFM) SLP anomalies



Appendix

→ Temperature anomalies, AMO sensitivities experiments with CNRM-CM5



Appendix

→ Winter SLP anomalies, AMO sensitivities experiments with CNRM-CM5

SLP anomalies after Pinatubo

CTL experiments : 13 members; PINATUBO experiments : 13 members

warm AMO corresponds to year 1991 and cold AMO to 2153 in these perfect model experiments

level of significance has been computed from a t-test considering a boostrap resampling (mean difference of 13 members) of the two sets of experiments

First winter (DJFM) SLP anomalies